PROCEEDINGS

OF THE

AMERICAN ACADEMY

OF

ARTS AND SCIENCES

Vol. LX.

FROM MAY 1924, TO MAY 1925.

BOSTON:

PUBLISHED BY THE ACADEMY.

1925.

INTELLIGENCER PRINTING CO.
LANCASTER, PA.

General
amer. acad. arts & sci.
exch. 8

CONTENTS.

Proceedings of the American Academy of Arts and Sciences.

Vol. 60. No. 1.— June, 1925.

(SHALER MEMORIAL SERIES.)

THE GEOLOGY OF ASCENSION ISLAND.

By Reginald A. Daly.

With Twenty-one Plates.

THE GEOLOGY OF ASCENSION ISLAND.

By Reginald A. Daly.

Received May 26, 1924. Presented October 8, 1924.

CONTENTS.

Introduction; Acknowledgments.

THE islands of the deep oceans have geological importance out of all proportion to their individual areas or their total area, when compared with equal areas of the continents. Small as it is, a deep-sea island tells us practically all we shall ever directly ascertain concerning the nature of the solid suboceanic material throughout a much more extensive region. Thus, from a few thousand relatively minute patches of dry land geologists must glean most of their detailed data for about one half of the earth. Investigations in geodesy, seismology, the earth's magnetism, paleogeography, isostasy, diastrophism, and petrology cannot be completed until the information from the deep-sea islands have been brought to book.

All of these islands seem to be volcanic. Their rocks indicate the composition of subcrustal or intercrustal magmas. Since the island cones have been built up from the bottom of the sea, 3000 to 6000 meters below the surface, the petrologist and volcanologist have here the advantage of being able to study the products of each truly enormous volcano at a late stage in its growth. None of the purely volcanic cones on the continents is comparable in height or volume with any one of many deep-sea volcanoes. When the explorer lands on an oceanic island, he begins his study at a contour line between 3000 and 6000 meters above the base of the pile, without the discomforts and expense which usually accompany exploration at similar altitudes on the lands. The study of the late stages in the growth of great volcanoes is, then, specially favored among the islands of the deep sea.

Moreover, in a few cases, oceanic eruptions have brought to view fragments of the solid crust on which the respective cones have been built. In this way precious information regarding the evolution of the ocean-basins, paleogeography in general, and other problems of the first rank has been secured. If for no other reason, an intensive study of every oceanic island is amply warranted. Since the geological mapping of this half of the earth demands much less work and expense than the other half, there is no good reason why the detailed mapping of the deep-sea islands should not be completed within a few decades. This systematic and comprehensive work is not likely to be undertaken by governments. It demands private enterprise, and, ideally, private endowment on a scale so large that the study shall be continuously pursued by experts consecrated to the working out of a great synthesis. Meantime the less satisfactory process of getting informa-

tion by individual studies pursued during independent expeditions is slowly but surely proving the significance of the oceanic islands.

Charles Darwin, Renard, Melliss, Prior, Reinisch, and others have illustrated the point from Ascension and Saint Helena Islands. No adequate geological map of either island has, however, been published. The opportunity of making geological reconnaissance maps of both was accorded to the writer during the year 1921. This paper summarizes his observations on Ascension; a second paper, on Saint Helena, will, it is hoped, be printed in these Proceedings after the lapse of a few months.

The geological part of the map of Ascension (Plate I) is the product of twenty-seven days of field-work (October 30 to November 25). Much more work could, of course, have been profitably devoted to the work, but steamer sailings and other considerations prevented the more thorough study.

The travelling and field expenses were defrayed from the Shaler Memorial Fund of Harvard University. They were low because the writer was the guest of Major C. A. Tennyson, Commandant of the island, which had long been under the control of the British Admiralty and noted on their books as a battleship. In 1922 the administration of Ascension was transferred to the Governor of Saint Helena, acting for the Colonial Office. Owing to the unlimited kindness of Major Tennyson and his staff of marines, the field-work was greatly facilitated. To him and to Rear Admiral F. C. Learmonth, Hydrographer to the Royal Navy, who donated charts of the island, the writer's thanks are due. As noted below, Dr. J. S. Flett, Director of the Geological Survey of Great Britain, generously presented a number of thin sections of Ascension rocks. The writer is specially grateful to Dr. H. S. Washington, Mr. E. G. Radley, and Miss Helen E. Vassar for the care which they have taken with the seven new chemical analyses of rocks.

The base-map used was the official chart, the quality of which is specially good. Its scale is about 1: 36,500. It shows relief by shading, supplemented by numerous indications of local heights, which were controlled by triangulation. Adding barometric data, material was secured for the drawing of a sketch-contour map, Plate I. Rough and imperfect as it is, this map gives an idea of the general relief. It bears a representative selection from the many soundings shown on the chart.

Previous Work.

In 1501, on Ascension Day, the island was discovered by de Nova, the Portuguese navigator. For more than three centuries it received little notice. In 1815, when Napoleon was sent to Saint Helena, the British Government annexed Ascension, and under naval control the first settlement, Georgetown, was founded. The Eastern Telegraph-Cable Company has here long had one of its most important stations, relaying transatlantic messages.

During 1819 the island was mapped by Lieut. R. Campbell, and in 1838 it was again mapped, and the surrounding waters sounded, by Lieut. G. A. Bedford of H. M. S. *Raven*. This second edition has been superseded by that made (1898–1901) by Capt. E. Y. Daniel, the chart now sold by the Admiralty and copied by the United States Hydrographic Office (chart No. 538; price, 40 cents).

As early as 1804 Bory de Vincent (Voyage dans les Principales Iles des Mers d'Afrique, 1801–2, 3 vols., Paris, 1804) published gossipy notes on Ascension and Saint Helena; these have now only historical interest. Of somewhat similar quality is the account given by R. P. Lesson, on pages 489–506 of the first volume on Zoölogy, resulting from the "Voyage autour du monde sur la corvette *La Coquille*, 1822–5" (Paris, 1826). The "Narrative of a Voyage to the Southern Atlantic Ocean in the years 1828–30, performed in H. M. Sloop, *Chanticleer*" (2 vols., London, 1834), by the naval surgeon, W. H. B. Webster, contains a little known but valuable description of the geology and natural history of Ascension. Webster anticipated Darwin in many important discoveries relating to the geology.

The classic pages of Darwin's "Geological Observations on the Volcanic Islands, etc." (pp. 40–82, 2d ed., London, 1876) give the best account of the island. The first edition (1844) was illustrated with Campbell's map; later editions with that of Bedford. Darwin's Journal of Researches (Voyage of H. M. S. *Beagle*, 1831–6) contains a few pages devoted to Ascension.

The *Challenger* Expedition (1873–6) resulted in several publications dealing with the island:

Narrative of the Cruise, by C. Wyville Thomson, vol. 1, part 2, pp. 927–9, 944, London, 1885;

Summary Report, by J. Murray, pp. 1237–41, London, 1895;

Report on the Petrology of Oceanic Islands (in vol. 2 of Report on Physics and Chemistry), by A. Renard, pp. 39–74, London, 1889;

The Atlantic, by C. W. Thomson, vol. 2, pp. 221–229, New York, 1878;

Notes by a Naturalist, by H. N. Moseley, pp. 487–489, new ed., London, 1892.

An entertaining, popular description of the island is given in Mrs. David Gill's "Six Months in Ascension" (London, 1878). Brief accounts are to be found in the Africa Pilot, Part 2, 5th ed., London, 1901; in the Encyclopaedia Britannica, 11th ed., article "Ascension," 1910; and in volume 13 (L'Afrique meridionale) of E. Réclus' Nouvelle Géographie Universelle (pp. 24–30, Paris, 1888).

The petrography of Ascension has been discussed by Darwin and Renard in the books already cited. G. T. Prior (Mineralogical Magazine, **13**, 257, 1903) gives additional notes. Another modern, but much more comprehensive, statement of the petrography has been published by R. Reinisch, who studied the specimens collected by members of the Deutsche Südpolar Expedition of 1901–3, volume on "Geologie und Geographie," Teil 2 (pp. 646–654, Berlin, 1912); a number of analyses are given.

In the April number of the Geological Magazine, 1922, the writer published a preliminary report on his exploration of the island.

Finally, note may here be taken of Faye's measurement of the force of gravity at Ascension, the result of which is given in the Comptes Rendus of the French Academy of Sciences (vol. 102, p. 651, 1886). As at Saint Helena, Fernando Noronha and Saint Thomas, he found gravity to be greatly in excess of its theoretical value.

Physiography.

Ascension Island lies just north of the parallel of eight degrees, south latitude, and centers on the meridian of fourteen degrees, twenty-four minutes, west longitude. In plan it approximates to an equilateral triangle, measuring 12 kilometers by 9.5 kilometers. The circumference is about 35 kilometers; the area, about 97 square kilometers.

The base of the island-cone is near the top of the mid-Atlantic swell at the depth of nearly 3,000 meters below the surface of the sea (Figure 1). To east and west of the swell the Atlantic bottom has depths greater than 5600 meters. The Saint Helena cone, situated near the eastern foot of the swell, 1250 kilometers southeast of Ascension, has its base at the depth of about 4200 meters.

On a manuscript chart, kindly supplied by the Eastern Telegraph

Company, Ltd., of London, indicated soundings show the existence of a broad, dome-shaped, relatively shallow area of the bottom. The minimum depth found in this area is 830 fathoms, or 1518 meters, at a point bearing about N. 30° W. from Georgetown and distant 16.5 kilometers therefrom. Three kilometers to the northwest of that point is another sounding, of 860 fathoms or 1573 meters. Between the shallowest point and the shore of Ascension, three soundings, at

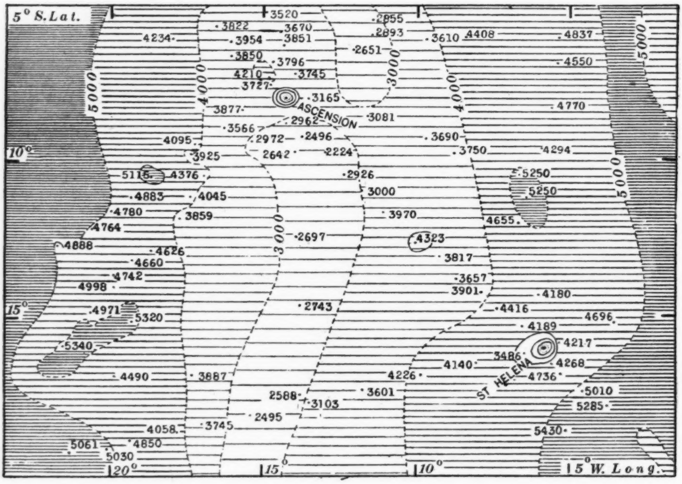


FIGURE 1. Position of Ascension and Saint Helena Islands in relation to the mid-Atlantic swell. Depths in meters.

1100, 1018, and 1178 fathoms, seem to prove that the dome-shaped area rises from the general surface of the mid-Atlantic swell, quite independently of the Ascension cone; another volcanic center may be indicated.

To the westward of Ascension the soundings are sufficiently numerous to give an idea of the submarine slope on that side. From the shore at Georgetown to the apparent base of the cone to the northwestward, a distance of about 13 kilometers, the average slope is close to 10°. From sea-level at Georgetown to the top of the Peak the average slope is 6° 40′. From the summit of the Peak to the base of the cone to the northwestward the slope is about 8° 30′. Off South-

east Head the submarine slope is much steeper; a sounding at 39 fathoms or 71 meters is spaced only 1100 meters from a sounding at 400 fathoms or 731 meters, giving a slope of 31°. Probably, however, the mean slope of the cone as a whole is not very different from that of a typical basaltic volcano rising from the floor of the ocean.[1]

As usual the horizontal distance between the shore-line and the 50-fathom isobath is considerably greater than that between the 50-fathom and 100-fathom isobaths. The break-of-slope at the outer edge of the coastal shelf is located close to the 50-fathom line. In illustration the slopes off Georgetown may be noted:

0–50	fathoms	1:40
50–100	"	1:10
100–200	"	1:6
200–500	"	1:3
500–700	"	1:5

The island lies in the trade-wind belt. The mean temperature of the air at the shore (Georgetown) is 85° F. and at the elevation of 2000 feet (610 meters) on Green Mountain, about 75° F. In spite of these temperatures the field-worker is kept comfortable by the strong, persistent wind. In fact Ascension is widely known in naval circles for its health-giving climate. The conditions are arid to semi-arid. The mean annual rainfall is not far from 20 inches (50 centimeters), but most of the rain falls during the autumn months of March and April, often in the form of "cloud-bursts." The porous nature of the rocks prevents any significant storage of water except by the use of catchments surfaced with cement, at high cost of labor and material. These catchments, totalling several acres in extent, are all situated near the top of the highest point, the summit of Green Mountain, some eight kilometers from Georgetown. At the very top is a large dew-pond, kept filled by the drip from planted bamboos; the precipitation of water from the humid air is rapid enough to preserve a depth of a meter or less throughout the dry season. The water piped from Green Mountain has proved insufficient for the inhabitants of Georgetown, who have long relied on the distillation of sea water for a large part of their supply.

The famous "rollers," breaking on the shores of Ascension and

[1] See O. Krümmel, Handbuch der Ozeanographie, Stuttgart, **1**, 97, 1907; F. Dietrich, Untersuchungen über die Böschungsverhältnisse der Sockel oceanischer Inseln (Inaug. Diss., Greifswald, 1892); G. W. Littlehales, Paper 95, United States Hydrographic Office, Washington, 1890.

Saint Helena, are explained in the Hydrographic manuals as due to swells set going by storms in the North Atlantic; accumulating evidence tends to confirm this theory.

Thin deposits of phosphate, on the basaltic flows, occur at many places. These will be described by Professor E. S. Larsen and G. Richards in a special paper.

Ascension is entirely volcanic, except for some small patches of beach material thrown up by storm waves. From the time of its discovery no sign of volcanic activity, not even a hot spring, has been reported, though geologically the island is extremely young. The chart shows the sites of forty-four vents, including a distinct vent probably represented in Boatswain Bird islet, near the eastern end of the main island. Adding other, smaller vents, the total number is at least sixty.

The highest point is the top of The Peak (2817 feet or 858 meters above sea), which itself is the highest part of the complex called Green Mountain (Plate II, *A*). Southward from The Peak to sea-level the mean slope is three times as rapid as that on the opposite side; to eastward the mean slope is nearly twice that on the west. The asymmetry of the island's profile is further expressed by the special development of high cliffs and cliffy slopes in the eastern and southeastern parts of the island. Even before the visits of Lesson, Webster, and Darwin, the intelligent commandants of Ascension had remarked on the lack of symmetry in the individual cones, which in many cases are steeper to windward (the southeast) than in the opposite direction. The strong trade-wind is the obvious direct cause of the more rapid, initial accumulation of ash and cinder on the leeward side of each vent. The initial asymmetry has been increased by the erosion of the windward slopes and drifting of the finer material to leeward. This thinning and weakening of the structure on the windward side has caused the lava, later rising in the vent, to break through or over the rim on that side. Typical breached cones have been thus produced.

More than half of the island is surfaced with scoriaceous flows of basaltic or trachydoleritic composition; pyroclastic beds, though common, are subordinate in volume. There is no reason to doubt that the great composite cone is also chiefly basaltic at all depths below the present land-surface. Important trachytic masses are intercalated with the femic flows and pyroclastic beds or rest upon these. One may assume similar interruption of the basaltic complex by other local, subordinate bodies of trachyte, down to some depth below sea-level. Clearly, however, trachyte is not the rock on which

the visible island is based. Darwin speaks of the trachyte as "fundamental" and the basalt as characteristically "overlying" the trachyte, having been erupted "at the base of the great central mass of trachyte." The true relations of the two types of lava are described below.

For the convenience of the reader the following table (Table I) has been compiled, giving a brief, preliminary description of the named cones and vents, which are classified according to their essential features. Heights have been taken from the chart or from notes of barometric readings.

TABLE I.

BASALTIC MASSES AND OTHER FEMIC MASSES.

(Masses of composition other than basaltic are specially designated.)

Exogenous lava-dome (due to local eruption without definite crater):
Bears Back, 800 feet. (Plate IV.)

Fissure-eruption:
On Southeast Head (several small craters opened on the fissure) — trachyandesite. (Plate VIII.)

Dominantly or wholly lava-formed cones:
Dark Slope, 763 feet — breached. (Plate XI.)
Driblet west of Dark Slope.
Table Crater, 640 feet — breached.
Lady Hill, 1181 feet.
Slag cones 800 meters W. S. W. of Lady Hill summit.
Three driblets, northeast foot of Sisters Peak.
Landing Pier cone, Georgetown, 80 feet (scoria cone) — trachydolerite.
Hayes Hill, 106 feet — trachydolerite. (Plate XXI, *A*.)
Cat Hill, slag-cone, 280 feet.
Twelve driblet cones, culminating at the west end of the series in Booby Hill.

Composite cones, composed of flows and pyroclastics:
Saddle Crater, 422 feet.
South Gannet Hill, 749 feet.
Round Hill, 450 feet.
Horseshoe Crater, 394 feet.
Mountain Red Hill, 1786 feet. (Plate X, *B*.)
Sisters Peak, 1460 feet. (Plate III, *A*.)
1012-foot cone N. W. of Sisters Peak.
1187-foot cone S. E. of Sisters Peak.
Travellers Hill, 1174 feet.
Thistle Hill, 1080 feet.

Butt Crater, 740 feet.
Street Crater, 787 feet.
Three unmapped craters between Street and Hollands craters.
Sisters Red Hill, 905 feet.
Hollands Crater, 654 feet. (Plate IV.)
East Crater, 743 feet. (Plate IV.)
Breached cone, north foot of Bears Back, about 500 feet.
Upper Valley Crater, 803 feet.
Crater Cliff cone, 186 feet.
Southeast Crater, 1146 feet.

Dominantly or wholly pyroclastic cones:
South Red Crater, 546 feet.
Southwest Red Hill, 731 feet.
613-foot cone N. W. of Dark Slope (has effluent flows).
Perfect Crater, 1020 feet.
The Peak, 2817 feet. (Plate II, *A*.)

Trachytic Masses.

Endogenous domes or crater-fillings, not visibly affected by axial subsidence:
Pillar Bay dome (probable).
Cocoanut Bay body, a relic, perhaps eviscerated by explosion.
Ragged Hill dome, 944 feet.
Green Mountain dome, 2490 feet; rose in a large basaltic caldera; thick overflows of trachyte; on the east affected by a second caldera explosion, The Peak cone of basaltic tuff and ash being built in this cavity.
Weather Post dome, 1990 feet; thick overflows of trachyte; affected by a major explosion at the Devils Cauldron (caldera) and probably by a still greater explosion, which formed the depression between Weather Post and the ridge running north from White Hill. (Plate XV, *A*.)
White Hill dome, 1723 feet; thick, stubby overflows of trachyte.
Little White Hill dome, 552 feet; rose in center of older explosion-crater of which much of the basaltic rim is well preserved. (Plate VII.)
Wig Hill dome, 475 feet; veneered with basaltic scoriae. (Plate IX.)
Southeast Head dome, 479 feet; probably extended by thick overflows of trachyte; fissured and flooded by a very young flow of trachyandesite. (Plates VIII and IX.)
Boatswain Bird Islet, 323 feet; probably an independent dome of monolithic trachyte. (Plates XIX and XX.)
Dome (?) at southeastern foot of Bears Back; small exposure.
Stubby flow 500 meters southeast of 1187-foot summit on Sisters Peak ridge.
"The Crags" dome (1 km. N. N. W. of Sisters Peak), about 300 feet; largely covered with younger basaltic ash and lavas.

Cross Hill dome, 868 feet; rose inside an older basaltic crater-rim; at least one outflow of trachyte; after solidification covered by basaltic, scoriaceous flows and cinders, which issued through the body of the dome. (Plates II and X, *A*.)

Endogenous domes or crater-fillings, deformed by axial subsidence:

Riding School dome, 800 feet; rose in older basaltic caldera-rim; thick, stubby overflows. (Plates X, *B* and XI.)

"Drip" dome, 900 feet, at southern foot of Sisters Peak ridge; rose in older basaltic crater or caldera; overflows of trachyte perhaps represented in outcrops of this rock east and northwest of Thistle Hill summit.

The many cones and domes, like the lava flows, have forms almost ideally constructional (Plates II–V; X, *A*; XIV, *A*; XVII). Several vents and flows have such freshness of aspect as to suggest their origination perhaps since the beginning of the Christian era; in any case the island is manifestly very young. Erosion has affected constructional forms of some of the trachytic bodies and also the older basaltic flows at Southwest Bay. The imposing sea-cliffs at the eastern side of the island, as well as those bounding Boatswain Bird islet (Plates XIX and XX), imply wave-action during many centuries. However, the cliffed trachytes and underlying tuffs are comparatively weak rocks, so that even for this part of Ascension one need not assume an age greater than a few tens of thousands of years. If the long escarpment at Southwest Bay is a true sea-cliff, that erosion must have taken several millenia, for the rocks truncated by the cliff are massive flows of strong basalt. In spite of these exceptions the physiographic development of the island, its march in the erosion cycle, has just begun. It is possible that the whole mass above sea-level has been erupted during post-Glacial time; the age of the much greater mass of the cone, below sea-level, is quite unknown.

It may be added that the writer found no definite evidence of either crustal uplift or crustal subsidence at Ascension; nor clear proof that this island was affected by the six-meter, probably eustatic, lowering of sea-level, registered at Saint Helena. The shore rocks of Ascension may be younger than that shift of sea-level; or, antedating it, the marks of the higher stand of the sea may have been drowned by later subsidence of the island. These and other unanswered questions bearing on the stability of the crust in this region invite further study.

General Structure.

In the field one cannot usually make sure distinction between basalts and trachydolerites. The latter are demonstrated at Hayes Hill, at the Landing Pier, Georgetown, and probably at the ridge a few hundred meters north of the summit of Cross Hill, but doubtless there are other occurrences. On the map (Plate I) no attempt has been made to indicate by a special design the distribution of the trachydolerites, which are mapped along with all the other types more femic than trachyte as "rocks of basaltic habit." It should be noted also that the non-stippled area on Southeast Head, Plate I, represents the flood of trachyandesitic lava there flooding the trachyte.

On Plate I the trachytes are shown by a stippled pattern except in the case of each of the smaller bodies, for which a design in solid black was chosen in order to facilitate reading of the map; this difference of design for the trachytes has no other significance.

Basaltic Cones.

The femic masses entering into the constitution of those composite piles which also include trachyte will be considered on later pages dealing specially with the trachytic bodies. Most of the purely basaltic cones present no unusual characteristics, so that a detailed account of each does not seem warranted. Some data relating to them are given in Table I; only a few additional notes will be added.

Reference has already been made to the prevailing asymmetry of the cones and to the related development of breached cones and craters. Good examples of these are found at Hollands Crater, East Crater (Plate IV), and Table Crater. In an analogous manner effluent discharges of lava have tended to be particularly abundant on the windward sides of Cross Hill, Spoon Crater cone, and South Gannet Hill.

The breached East Crater affords an example of axial subsidence which is unique among all the cases where basaltic lava has risen in the craters of the island. From the foot of the breaching overflow its surface rises at an angle of about 20 degrees to the rim of the crater, where the chaotic surface of the same flow sinks rapidly, about 25 meters, to the center of the crater. This late subsidence of the crater-floor was probably due to withdrawal of the magma in depth, though mere thermal contraction of the freezing magmatic column may have

played a part. Similar axial subsidence has taken place at the Riding School and "Drip" domes of trachyte.

Special note may also be made of the Bears Back (Plate IV). This plateau-like mass is not fully understood. It seems to be monolithic and not made up of several flows of basalt. The lateral scarps are rather steep on all sides, indicating high viscosity at the time of eruption. The whole eminence may, indeed, represent a flattened dome, formed by a single exudation of very stiff basalt. Since, however, trachyte crops out at the foot of the Bears Back, it is not possible to exclude the hypothesis that the mass is a low, broad dome of trachyte which has become veneered with a thick flow of basalt.

Small, steep-sided cones, wholly composed of driblet flows of basalt, are well represented in the island. The best examples were found in two different sets, each set aligned as if the respective vents were opened along a single fissure.

One of these groups is situated near the 550-foot contour, 600 meters north of Sisters Peak (1460-foot summit) and an equal distance W. N. W. of Sisters Red Hill. Here three driblet cones, ranging from three to twelve meters in height, are arranged on a straight line, 60 meters in length; this line passes through the top of Sisters Peak. The well-like vents are cylindrical down to the levels where they are choked with débris, but in one case at a depth of about nine meters the pipe widens into a spacious, domed chamber. Evidently during activity the vent occupied by the molten lava enlarged downward for some distance. The highest cone, in the middle, is a composite, made up of blobs of lava that issued from three adjacent pipes, of which the centers lie on the line joining the other two simple cones. The external slopes of the little cones are steep, from 30 to 60 degrees, compared with the horizontal plane.

The other set of driblets includes the main crater of Booby Hill, southwest of Green Mountain. East of it are eleven other driblets distributed along a line about 500 meters long. The Booby Hill (its top 30 meters above the surroundings) and two adjacent craters are relatively large and have been breached by strong flows of basalt. The other nine cones, more symmetrical, range from two to seven meters in height. The fissure which fed probably all twelve vents lines up with a major vent south of Spoon Crater cone, suggesting a genetic connection.

Basaltic Flows.

Most of the areas covered by the young and rough lava flows of basaltic habit — locally called the clinker-fields — are shown on the naval chart by a special design. The complete mapping of all the individual flows exposed, if possible at all, would demand much more than a month of field-work. Those which could be mapped with some accuracy may be listed:

1. An extensive, fan-shaped flow from a small crater close to the most easterly of "The Crags," north of Sisters Peak. The length and width are each about three kilometers. The flow entered the sea along a wide front, from Bates Point to English Bay (Plate III, *B*). This may be called the Comfortless Cove flow.

2. A 2.5-kilometer flow from the eastern flank of Sisters Peak, which has certainly been one of the centers most recently active. This flow, cliffed by the sea-waves on both sides of Porpoise Point, east of East Crater, may be called the Porpoise Point flow.

3. A one-kilometer flow from a well-defined crater just north of the Bears Back plateau.

4. A one-kilometer flow, directed northward from a crater (not indicated on the chart), 700 meters W. S. W. of the top of Lady Hill. Near the site of the Wireless Station (now dismantled) this scarps on an older flow, probably from the same vent. These may be called the Wireless Station flows.

5. A series of flows emanating from an opening at the foot of Dark Slope cone and reaching the sea, 2 kilometers to the westward. The youngest of them cascaded over the 60-meter cliff facing Southwest Bay. These basalts are distinguished among all the greater flows of the island in being markedly porphyritic, with phenocrysts of feldspar; they may be called the Southwest Bay group of flows.

6. A broad flow from the southern flank of South Gannet cone, measuring about 1.5 kilometers in length, as well as in width. It vies with the Porpoise Point flow in being the roughest, most chaotic, on the island.

The average exposed flow of basaltic lava has much smaller volume than any of the first six flows above listed. Each individual output of lava at these great heights from the base of the Ascension pile was thus comparatively small; the behavior of the mechanism was normal for the closing stage of the life of a great volcano.

About nine-tenths of the visible flows may be described as of the chaotic type. By fracture, shear, and rotation each rugged mass has

yielded to the complex tensions set up in the upper, more solidified shell, which slid on, or was sheared across, the less rigid, hotter, lower part. The forms developed are of two kinds. (1) The flow shows a succession of transverse, gaping fissures or trench-like depressions, separated by flat-topped, sharp ridges or by lines of spires — the whole simulating the crevasse-serac system of an alpine glacier. Or (2) the flow exhibits the even more irregular surface of typical block-lava (Plate V, *A*). In this case the blocks tend to be smaller than those of the Hawaiian flows and have dimensions more like those of the blocks in Vesuvian lava flows.

A few of the Ascension flows approach the smoother, ropy or pahoehoe type, though even these become chaotic where the underlying surface has strong irregularities. Perhaps the best illustrations of the smooth type are to be found in the Southwest Bay group of flows. These are characteristically jointed, in rough columnar fashion, to the depth of five to ten decimeters. Weathering has opened the joints somewhat, giving the appearance of a floor composed of large, closely set boulders. The very massive lava constituting the northern slope of the Riding School cone is bouldery, on a cyclopean scale. A flow from the foot of Mountain Red Hill, northwest side, is similarly bouldery, the round masses measuring three to ten meters in diameter. This flow measures 200 by 100 meters. Its initial viscosity was high, causing the constructional scarp to be steep. While differential weathering may be partly responsible for the peculiar habit of this particular flow, the cause is by no means apparent.

The basaltic flows are seldom as much as 20 meters thick; a common average thickness is 6 meters. The thickest observed body of basalt constitutes the lower, greater part of the cliff surrounding Cricket Valley (Figure 7). From the top of this monolithic mass to the ash-covered floor of the caldera is a vertical distance of 60 meters; the total thickness of the sheetlike monolith must be greater. Except at and near the top it is trappean and almost devoid of vesicles. Its mode of emplacement is not clear. In the sections of Figure 7 it is represented as a thick flow, but possibly it may be the remnant of a lava-lake in a crater, a lake which was frozen in situ and later in part destroyed by the caldera-explosion.

Some of the flows bear well individualized hillocks of two kinds; neither type is very abundant.

The one kind is the tumulus, turtle-shaped or shield-shaped, one to five meters high, ten to twenty-five meters long, and five to ten or fifteen meters wide. These tumuli are essentially like those of Hawaii

and were caused by local, hydrostatic or gaseous pressures exerted by the still fluid material against the solidified, surface-shell of the flow. In some instances the uplifting pressure may have been due to steam generated by the volatilization of water which was overrun by the hot lava, but it seems clear that the liquid lava itself has also carried the pressure.[2] As usual the surfaces of the elliptical domes are fissured because of breaking tensions developed during their growth. The resulting crevasses are from one to three meters wide on the tumuli seen on the flows of the Southwest Bay group.

The other type was described by Darwin. It is best illustrated on the older of the two Wireless Station flows, on the flat east of Cross Hill. They are steep-sided cones, composed of highly scoriaceous basalt which is everywhere discrete, after the fashion of some scoriaceous agglomerates (Plate V, *B*). Their general appearance is that of a driblet-cone or hornito. In no case, however, could a central pipe be discovered.

Every part of a moving lava-flow shares the properties of ideal liquids and solids. Even the most fluent part is doubtless characterized by some elastic stress and corresponding strain. The chilled surface-phase has a much higher elastic limit, but this stiff part of the flow is also elastico-viscous. Its rigidity is higher, the decay of its rigidity slower, than in the case of the interior phase of the moving flow. The displacement of the surface-phase is therefore usually accomplished by bodily sliding over the more fluent lava beneath — a kind of landsliding. As in ordinary landsliding, the more rigid surface-shell downstream tends to be folded and broken by transverse shears. Back of the frontal scarp, itself largely caused by the forward thrust of the surface-shell, are found isolated pressure-ridges, grouped anticlines and synclines, anticlinoria, synclinoria, overthrusts, and underthrusts. Upstream the surface-shell is regularly broken by many transverse fissures, caused by the tensions set up by the displacement, sliding, on the inclined, uneven floor.

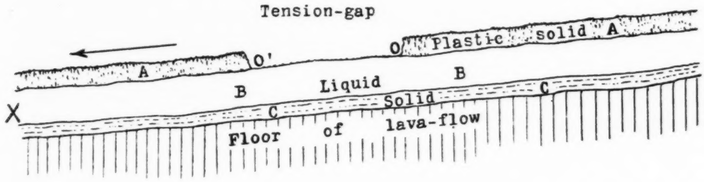
Figure 2 is a diagrammatic section of one of the flows near Comfortless Cove. It illustrates the combination of compressional and tensional features, just described. Similar features characterize basaltic flows in many other fields of lava. Their bearing on the new hypothesis of continental displacement was specially studied. A digression on this important question may be permitted.

The hypothesis of continental migration is probably best phrased in

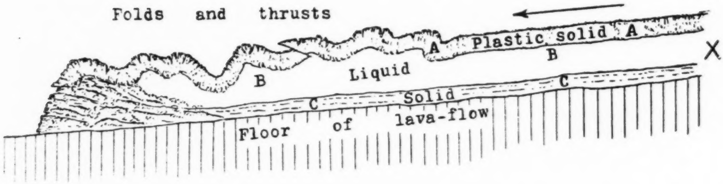
---

2 Cf. R. A. Daly, Igneous Rocks and Their Origin, p. 134, New York, 1914.

the sense of the following question: Have the cordilleras and the great basins of the Atlantic or Arctic type been developed by continental *sliding?* Is the continental crust analogous to the surface-shell of a lava flow which has moved? Is the earth-shell on which the crust rests an elastico-viscous substance, analogous to the hot, glassy, in-



<u>Upstream</u>: Chilled, solid layer, A, slides on hotter, viscous layer, B, which rests on chilled floor-layer, C. Under the tension layer A parts at O. Sliding causes cliffed depression O — O'



<u>Downstream</u>: Folds and thrusts in layer A, caused by its sliding on layer B through the distance O — O'.

FIGURE 2. Longitudinal section (diagrammatic) illustrating development of anticlines, synclines, thrusts, and tension-gap in superficial, plastic-solid phase of a basaltic flow, because of the sliding of that phase on the "liquid" lava of the interior of the flow. Arrows show direction of flowing and sliding. The upper part of the section is continuous with the lower part at the point "X." Below the gap, O–O′, the layer B was quickly chilled to rigidity. Section not quite in true scale; clifflet at "O" or "O′," from 3 to 5 meters high.

terior phase of the moving lava flow? Has the continental crust become deleveled by secular processes, so far that continental sliding became inevitable? Was the friction, static and kinetic, opposing the

slow movement of continental blocks, so low that there remained energy sufficient for the folding of geosynclinal sediments downstream? One may go further and ask if the parallel between continental displacement and the flowing of physically heterogeneous lava is not a true homology rather than merely an analogy.

In any case the writer believes that the daring hypothesis of extensive continental migration in past times would be clarified if it were phrased in terms of continental sliding rather than in terms of continental flotation. A sliding theory seems much more feasible than a "drift" theory. If the continents are, and always have been, truly floating, they could have been displaced only by a dragging or pushing force other than pure gravity; an efficient force of that kind has not yet been discovered. Sliding means the operation of pure gravity, displacement due to the dead weight of the continent involved. In passing, it may be pointed out that the imagined secular develeling, which gives potential, is not incompatible with the rule of isostasy.

Leaving these difficult but fundamental questions, suggested by the characteristics of many Ascension flows, the writer will note a detail which he has seen nowhere so well illustrated as in the Comfortless Cove flow. Not far from the cove itself one can find places where the surface of scission between the sliding "crust" of the flow and the underlying, weaker, hotter phase is now exposed to the air. The lower phase, still largely vitreous, is there grooved and striated. Its surface is roughened by serrate ridges and points, resembling sharks' teeth. These many projections point downstream and may be explained as due to elastic and viscous reactions in the glassy lava where relieved of the weight of, and elastic stresses induced by, the heavy "crust" which had just slid away. The points of the projections stand two to five centimeters above the general surface of the striated, glassy basalt (Figure 2*a*).

Contrasting with flows of the kind just described are a number of others in Ascension, which show a prolongation of liquid flow after the chilled surface-shell had become laterally anchored. Lava tunnels of the familiar sort were thus formed, though not in great number or of large size. In most instances their roofs have collapsed, except for short distances. One of the roofed relics, about 20 meters long, 3 meters wide, and 1–2 meters high, was found just below a small driblet cone at the western foot of the Dark Slope cone. This tunnel plunges southward at the unusually high angle of 30 degrees. Other lava tunnels, along the shore, are the loci of spouting horns which are quite spectacular during times of heavy surf.

Locally the tunnel streams of hot, fluent lava have worn pronounced channels or gutters, reaching as much as a meter in depth, in the older rocks. Such runnels seem to be represented on the brink of the cliff facing Southwest Bay, where, however, the old cliff is largely mantled with lava, frozen in the act of cascading westward over the cliff. Other runnels, three to ten meters in width, were seen along the path from Cat Hill to the cemetery at Georgetown.

The depression between Little White Hill and the Southeast Head dome is the bed of a very young flow. This flow had attained a considerable depth in the depression when the supply at the vent was

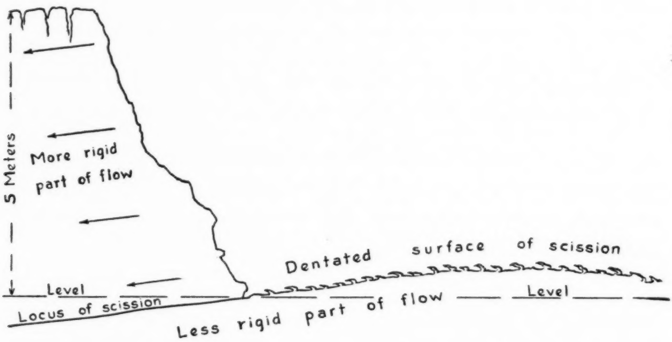


FIGURE 2*a*. Diagrammatic section illustrating the sliding of the upper, more chilled and rigid part of a lava flow on the underlying, hotter, and less rigid part; with resulting shark's-tooth projections on the grooved surface of scission (the glass here rapidly solidified by chilling).

stopped. A chilled surface-shell was formed and anchored to the sides of the valley. Then the still fluid lava beneath continued to flow in the direction of Southeast Bay. The anchored crust, thus left without support, settled in the middle, leaving on the valley sides moraine-like patches of itself, two to six meters above the general surface of the sunken, chaotic chill-phase (Figure 3). This flow deserves further study, but it seems to furnish another example of the principle described already by Glangeaud, working in the volcanic district of central France. He also found evidence of valley-flooding by lava, followed by subsurface draining of the fluid magma and consequent formation of terrace-like masses of lava on the sides of the valley.[3]

[3] P. Glangeaud, Bull. 135, Service carte géol. France, p. 57, 1913.

A similar process may account for a moraine-like ridge of lava skirting the northern slope of Southwest Red Hill.

Generally the basaltic flows of Ascension are initially black to dark gray at surface and floor as well as at intermediate levels. Among the more extensive flows this rule seems to have no exception. To depths of a few centimeters the brown tint of weathering is characteristic of the older flows, but apparently at no place has ordinary weathering produced the deep red color, so common in the scoriaceous phases of once deeply buried, basaltic flows, as in Saint Helena, the Hawaiian Islands, Samoan Islands, and elsewhere.

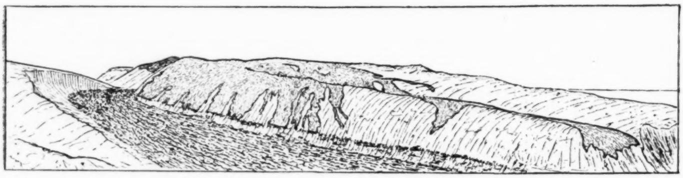


FIGURE 3. Sketch of a young flow of basaltic habit which occupies the floor of the valley between the Southeast Head plateau, flooded with trachyandesite (background), and the Little White Hill crater rim (left end of picture). The subsurface draining of the lava in the valley seems to have thinned that flow, leaving ragged, terrace-like patches on the slope of Southeast Head.

On the other hand, some short, thin flows, especially noted around Mountain Red Hill and along the southern side of the old caldera-rim of Green Mountain, are distinctly red and seem to have had that color from the time of consolidation. Their tint is much like that of many of the tuff-ash cones of the island. The specially high oxidation of these pyroclastics seems referable to the prolonged influence of steam passing through the vents where the material had temporarily rested. That well recognized effect of fumarolic emanation may likewise explain the magmatic reddening of the small-volume flows just mentioned. The gray and black flows escaped prolonged steaming, except where they happened to cross the sites of fumaroles or steam vents, active after the flows had come to rest. At such points local reddening of the rocks is to be expected.

The rules regarding color, stated for Ascension, seem to apply to basaltic regions in general. Hence the striking red phases of formerly buried flows of basalt, seen in the cliffs of Saint Helena, Samoa, Hawaii, etc., were probably not so colored at the times of their respective eruptions. Neither is explanation by weathering satisfactory. Perhaps

in many of these cases the reddening is an effect of the passage of hot steam, permeating the piles of lava, especially the scoriaceous surface-phases and floor-phases, for a long time after the flows were solidified. That deeply buried flows have actually been charged with steam, after the fashion of a steam-pack, is indicated by explosions of the caldera type.

Trachytic Masses.

Though the existence of alkaline trachytes in Ascension has long been known, their mode of occurrence and structural relations have not been hitherto described in detail. These features of the geology are worthy of close attention and it is fitting that the data of Table I should be considerably expanded in the present paper. As shown in the table, most of the trachytic bodies are crater-domes or outflows from domes. One may well doubt that so many endogenous domes are anywhere else to be found in an area so small, and that, throughout the world, the completeness of exposure and of preservation of initial forms in such number can be surpassed.

The simpler domes will be first described; then those more complex; finally certain small masses of more obscure relations.

Ragged Hill Dome. The Ragged Hill dome (alt. 944 feet, 288 meters) is one of the most perfect in the island. It rises from beneath the bedded ash-scoria-driblet cone of Southeast Crater (alt. 1146 feet, 350 meters), south of Green Mountain (see Plate I and Figure 4). The base of the dome is concealed also by younger lava flows from Green Mountain, so that the height of the dome above these flows is only 30–40 meters on the north and about 80 meters on the south. The visible part is nearly circular, with diameters of 200 and 250 meters. Through erosion (insolation, wind, and rain) the dome has lost substance to the average depth of a few meters. This trachyte is charged with unusually large and abundant phenocrysts of feldspar. Fluidal banding is not conspicuous, but the dome structure is clearly indicated by the presence of a pronounced, concentric rifting; the plates dip away on all sides from the top of the dome, the angle of dip reaching as much as 35 degrees at the border of the mass. The platy structure appears to be due to thermal contraction. The trachyte contains many inclusions of vesicular lava, probably common basalt. The weathered surface is carious (Plate VI, *A*), and the hardened (silicified) shells and points are specially sonorous under the hammer. In hollows on the dome fresh feldspars, released by weathering, are concentrated.

From its position the Ragged Hill dome might be taken to be a lateral eruption from the Southeast Crater vent. On the other hand, the trachyte may have risen through an independent vent, as indicated, speculatively, in Figure 4. The underground relations are too obscure for certainty on the point. More evident is the steepness of the constructional slopes of the dome, showing the very high viscosity of the trachytic magma.

Little White Hill Dome. Like the last this dome (alt. 552 feet, 168 meters) has an initial form not complicated by effluent tongues, and it has not been greatly altered by erosion (Plate VII). The ground-plan is nearly circular; the diameter, about 150 meters. Below the normal, carious surface, due to weathering, the cliffy slopes

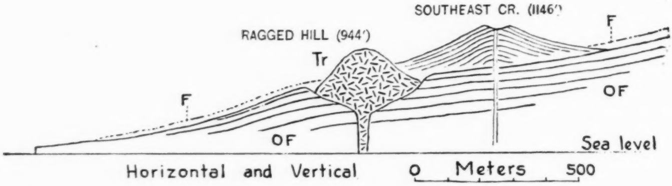


FIGURE 4. Section through Ragged Hill dome of trachyte (*Tr*) and the basaltic cone of Southeast Crater, both resting on older flows of basalt (*OF*). A young basaltic flow from Green Mountain (*F*) has partly submerged dome and cone.

display a fluidal structure. On the west, north, and northeast the light gray dome is surrounded by a continuous, crescentic, curving ridge of reddish, brown, and black ash and scoriae, evidently the rim of an older, basaltic crater, in the midst of which the trachytic dome arose. To the eastward the basaltic rim abuts against the independent dome of Southeast Head. Alternative explanations of this relation suggest themselves. Conceivably the Southeast Head dome is older than the explosive or other process responsible for the wide crater and represents part of its rim. On the whole, however, it seems more probable that the Southeast Head dome is younger than the basaltic crater, and during eruption overwhelmed the rim of the crater on that side. The second view finds support in the apparent absence of that amount of trachytic débris in the rim which might be looked for if the crater had been opened by explosion which affected the Southeast Head trachyte. On the south the waves of Southeast Bay have cut away the basaltic rim.

Wig Hill Dome. The remarkable Wig Hill body of trachyte (alt. 475 feet, 145 meters), faced by a grand sea-cliff, is the remnant of another steep-sided dome, which seems to have risen in the southern part of the same wide crater (Plates VIII and IX). The remnant, not yet devoured by the waves, is veneered to a depth of 5 to 20 or more meters with basaltic, scoriaceous agglomerate and driblet flows of vesicular basalt. The contrast in color of the veneering "wig" and the underlying dome is very striking. Their relative ages were not determined with finality. Viewed from a distance, the "wig" looks like a layer of older basalt, lifted and domed by the trachyte as it rose to assume the usual dome form. Close investigation shows the absence of the corresponding tensional effects in the rock of the "wig." Hence it seems better to assume the reverse age-relation, the "wig" representing basaltic eruptions through one or more vents penetrating the trachytic dome. The Wig Hill composite would thus be analogous to that at Cross Hill.

Cross Hill. From Georgetown Cross Hill (alt. 868 feet, 265 meters) has all the appearance of being an ordinary ash or cinder cone of basaltic habit (Plate X, *A*). The northern, western, and eastern slopes are largely underlain by yielding lapilli to depths locally reaching several meters. The southern slope and the upper part of the cone in general are superficially composed of a somewhat cemented, bedded ash or tuff, containing irregular spatter-bombs. The beds of tuff have been differentially eroded by the persistent wind and the occasional showers, especially on the southern side, where a prism approximating 60 meters in maximum thickness has been thus removed (*a* – *b*, Figure 5). If the existing cone ever had a crater, this has been eroded away. On the same slope one sees a few, thin, steep flows of scoriaceous lava interbedded with the pyroclastics. The tuff carries occasional small fragments of pale gray trachyte, conspicuous among the dominant black, brown, and reddish lapilli.

The trachytic fragments were probably derived from a dome of trachyte which underlies the mantle of tuff and flows (Figure 5). The depth of the mantle is about 75 meters at the top of the cone. On the northeastern side the basaltic mantle has been completely removed by erosion, over a considerable surface, from the 600-foot contour down to about the 200-foot contour. Small outcrops of the trachyte are seen also at the foot of the cone on the same side, and at the foot of the northwestern slope.

Just northeast of Government House on the slope of Cross Hill, a

large ridge-shaped outcrop of lava, probably trachydolerite, overlain by south-dipping beds of lapilli and moderately cemented tuff, forms part of an old crater-rim. The curving rim is also represented by another ridge to the eastward. Another, smaller part of the rim is probably to be seen at the foot of the southwestern slope of the cone. Elsewhere the old wall of the crater has been buried under younger pyroclastics or by lava flows from the interior of the island.

The history of Cross Hill seems, then, to be as follows: A trachydoleritic cone was built and eviscerated by explosion. At the center

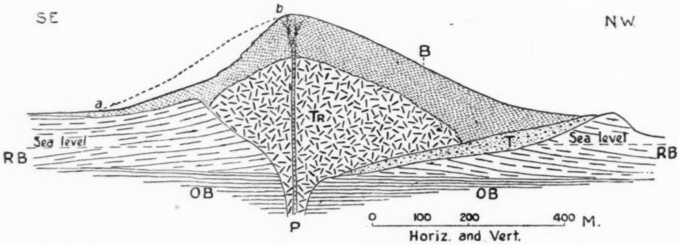


FIGURE 5. Section through Cross Hill, showing older basalts (*OB*) under a younger basaltic (trachydolerite) cone (*RB*), partly destroyed by explosion. In the resulting caldera tuff (*T*) was deposited. Later a monolithic dome of trachyte (*Tr*) was formed in the caldera. A thick cap of scoria, tuff, and breccia of basaltic habit (*B*) was then erupted upon the trachyte, through one or more narrow vents of the type shown diagrammatically at *P*.

of the resulting crater or caldera, highly viscous trachyte was erupted, forming a typical dome, much like that at Ragged Hill or at Little White Hill. A short, stubby outflow carried some of this stiff lava to the site of Georgetown, but most of the trachyte remained inside the rim, solidifying there with slopes of 20 to 30 degrees and with a height above the crater floor of nearly 200 meters. Then the central vent was again opened, probably by the cracking of the new dome; through explosion and outflow the trachytic dome was deeply veneered with the contrasted, femic lava.

The trachyte of the dome is a massive monolith, without notable flow-structure, crumbling at the top, and weathering to a rugged surface.

Riding School. The Riding School massif (alt. 800 feet, 244 meters) is an unusual volcanic type, which has claimed the attention of all visitors to the island. It consists of a basaltic-lava cone bearing

a relatively large crater which has been filled nearly to the highest point of its rim with monolithic trachyte. The basalt is black, dark red, or dark brown (weathered). Its viscosity on eruption must have been high, since the outer, constructional slopes are steep, measuring 30 degrees or more. The northwest slope is underlain by a single, very thick and massive, vesicular flow, which is broken into bouldery masses of cyclopean proportions. In fact, from the partial exposure of the old crater-rim, one gets the impression that it may be essentially the product of the same outflow. If that be true, an axial subsidence must be assumed, for a well defined crater-shaped depression had already been formed before the next important addition to the composite mass was made. The central depression could hardly have been formed by explosion; the outer slopes are not covered with the abundant pyroclastic deposits expected on that hypothesis. However formed, this crater-like depression was nearly circular and had a diameter of about 500 meters.

At the center of that depression a large body of viscous trachyte arose. This may have formed, initially, a true dome, but, if so, the new structure was unstable. A large fraction of the risen or rising trachyte flowed over the rim of the basaltic crater, eastward and northeastward, making a thick flow about 700 meters long. This flow, like many others in the island, is stubby, with steep terminal scarps. A much smaller outflow took place on the southwest side.

Perhaps partly because of the outflows, which may have drawn magma from levels below the surface of the central body of trachyte, this part of the surface subsided. Or withdrawal of magma at still greater depth may have operated. Or, thirdly, crystallization and purely thermal contraction of the vertical column may have had some importance. For one or more of these reasons the surface of the trachytic crater-filling became basined (Figure 6).

Ash, tuff, and lapilli, probably derived from The Peak or other eruptions of the Green Mountain region, formed well stratified beds in the new hollow (Plates X, *B* and XI). The beds themselves are strongly basined and it looks as if the axial subsidence continued for some time after the effluent trachyte had crystallized.

The monolithic floor of trachyte is comparatively impervious to water. According to Darwin some of the upper, finer-grained beds are lacustrine deposits. If these were properly identified by the present writer, they underlie a three-meter layer of basaltic lapilli which are very like those constituting so much of The Peak of Green Mountain. Neither that superficial layer nor the lake-beds beneath

seem to have been appreciably basined. The centripetal dips of the older, tuff-ash beds are commonly ten to fifteen degrees and have a maximum of about thirty-five degrees. Erosion has caused the projection of the stronger beds as crescentic ridges or cuestas, and has been specially active at the periphery of the basin; hence the slightly sunken "race-course" which has suggested the name of the Riding School.

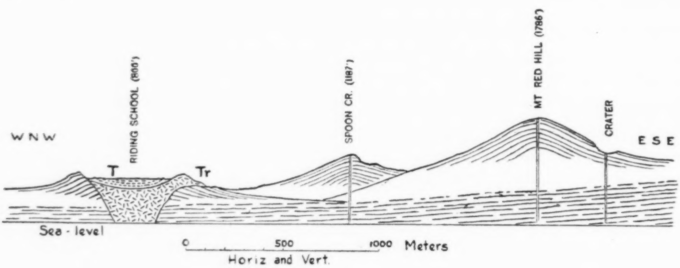


FIGURE 6. Section through basined dome of trachyte (*Tr*) at the Riding School, the corresponding "crater" filled with basined tuffs (*T*); section continued through Spoon Crater and Mountain Red Hill, both of basaltic habit.

The bedded rocks of the central depression were studied in the wall of wet-weather gulches and in a deep hole which had been opened by a prospector. Below the superficial layer of partially cemented, black to dark brown lapilli are the well-laminated silicious "lake-beds." These are white to pale gray and pale brown and are made up of trachytic or rhyolitic dust and volcanic sand. Some layers carry many angular fragments of white pumice. About ten meters is the exposed thickness of the more silicious beds; calculated from the dips the total thickness appears to be twice that amount.

The writer was unsuccessful in finding the bed of infusorial earth that Darwin reported from the Riding School basin.[4] The same result attended the effort of Mr. G. V. Douglas, geologist of the Shackleton-Rowett Expedition, to find it (verbal communication).

Silicious concretions, described by Darwin, occur in the layers of acid tuff and dust. One of these, collected by a member of the

---

[4] C. Darwin, Journal of Researches, p. 499, new ed., London, 1901; cf. C. G. Ehrenberg, Quart. Jour. Geol. Soc. London, **2**, part 2, 71, 1846, and Berichte k. Akad. Wissen., p. 140, Berlin, 1845.

Deutsche Südpolar Expedition, has been analyzed, as reported by Reinisch (page 648 of his memoir):

SiO_2	90.07
$Al_2O_3 + Fe_2O_3$	2.85
MgO	0.04
CaO	0.09
Alkalies	0.03
Loss on ign.	7.31
	100.39

When quite fresh the Riding School trachyte is a pale greenish gray. By exposure to the weather it is decolorized to a pure light gray or a pale yellowish gray, though the leading mineral constituents show no obvious changes. The pitted or carious surface of weathering is striking, especially on the windward side (Plates VI, *B* and XIII). Hoodoo-like towers, spires, and mushroom-shaped irregularities on the 20-meter to 30-meter cliffs have been developed because of the great difference between the strength of the normal trachyte and the strength of the silicified "veins," so characteristic here as in nearly all the trachytic bodies of Ascension. The origin of these veins will be discussed on a later page. The weaker parts of the trachyte weather to white dust and sand, chiefly composed of soda-orthoclase and anorthoclase.

Under the mantle of tuff and loose ash which covers the effluent trachyte on the Green Mountain side, the initial surface of the trachytic flow has been preserved. To the depth of from one to two meters this lava is strongly brecciated, because of the tensions which were set up in the superficial shell during flow. Even in that shell the trachyte is not vesicular in the sense of carrying rounded gas-pores like those of the neighboring basalt. The minute, angular spaces between the dominant feldspars give a porosity of a quite different type. The same characteristic applies also to the main body of the Riding School trachyte, as it does generally to the Ascension trachytes. It may be added that a stubby flow from the direction of Middleton Peak, and situated northeast of the Riding School, has likewise had its initial surface preserved by moderate burial under pyroclastics. Later erosion has exposed that surface, which has features like those of the flow just described from the Riding School mass itself.

The Riding School trachyte carries many angular and rounded inclusions of vesicular basalt.

"Drip" Dome. North of the road in the col between Travellers Hill and the Sisters Peak group of cones, there is a small slaggy, basaltic cone with a crater, 100 meters wide and opening to the west. This crater is not shown on the Admiralty chart. On its eastern side the cone passes under a large body of cariously weathering trachyte. The rock is largely covered with a thick layer of alluvial ash and lapilli, obscuring the form as a whole, but the relations seem to be that of a small dome, the surface of which has sunk at the central axis. The trachyte has a platy-fluidal structure, the plates dipping centripetally at angles of from two to five degrees, along a crescent-shaped area. On the eastern side a broad tongue of the dome trachyte, 200 meters long, flowed out and froze at an angle of about ten degrees. Then axial subsidence basined the surface of the dome. The result appears to be a homology with the basined dome at the Riding School.

Going north from the effluent tongue, one follows the edge of the main body of the dome trachyte, exposed in a cliff about twelve meters high. The trachyte is here monolithic and transgresses the red scoriaceous rim of an old basaltic crater, in which the dome arose. Lumps of the basalt are enclosed in the massive trachyte, which is curiously weathered into forms suggesting sections of a bee's comb and also concretionary shapes of great variety.

For convenience this trachytic mass may be called the "Drip" dome, one of the few drips (springs) of the island being located at this locality.

Flow of Trachyte North of the "Drip" Dome. Near the 1000-foot contour on the southeast slope of the 1187-foot cone of the Sisters group is a basaltic crater, not shown on the Admiralty chart. This crater is breached by a 175-meter flow of trachyte, which issued from this small crater itself. No true dome is represented. The flow is directed toward the south-southeast. It viscosity was very high; it consolidated on slopes varying from 20 to at least 35 degrees. The trachyte seems petrographically like that of the "Drip" dome.

"The Crags" Dome. A point one kilometer northwest of the 1490-foot Sisters Peak is near the center of a group of massive outcrops of trachyte. That farthest to the northwest is particularly conspicuous, showing a 30–40-meter cliff on the northern side. This whole assemblage of trachytic outcrops may be called "The Crags" (Plate I). Between the individual crags is a thick mantle of lapilli, bombs, and wind-blown volcanic sand, and the trachyte is also partly submerged under young, heavy, basaltic flows which issued from vents along the

northern base of Sisters Red Hill cone. The relations of "The Crags" trachyte are therefore not obvious, but it probably belongs to a single, relatively old, and hence considerably weathered dome, centering near the point first noted in this paragraph.

The trachyte has the habit normal for Ascension; it is of pale gray or yellowish-gray color, is monolithic at each crag, weathers cariously, and closely resembles the Cross Hill trachyte.

At one of the most southerly crags a 10-centimeter, angular inclusion of hornblende granite was found in the trachyte. Time failed for a thorough search for other inclusions of the kind; they cannot be numerous. The one actually discovered shows that the granitic fragments brought up at the Ascension vents are not confined to the explosion-breccias and tuffs. Apparently also it indicates the considerable depth from which the trachytic magma has come.

Bears Back Trachyte. At the foot of the southeastern slopes of Bears Back is a large outcrop of trachyte which underlies, and is older than, the basalt of the Bears Back plateau. The true form and relations of the mass represented could not be determined. As already observed, it may possibly represent the edge of a much larger, dome-shaped body centering under the Bears Back basalt. This trachyte is a common gray variety, not studied in thin section.

Green Mountain Dome. At the western end of Green Mountain the highest exposure of trachyte in Ascension is found, at the height of 2490 feet or 759 meters. This point is close to the vertical axis of one of the most voluminous domes of the island. Thence the stiff magma of the dome flowed out, westwards, northwards, northeastwards, and southwards. The longest of the flows, directed toward the west, is about two kilometers in exposed length. An outcrop of trachyte northwest of Spoon Crater cone, at its base, may be part of the flow just described; if so, the Spoon Crater cone is younger than, and in part built upon the lower end of the flow. In any case this basaltic cone is younger than the trachyte at its base.

Plate XIV, *A*, illustrates the habit of the trachytic overflows from the Green Mountain Dome center. The high initial slopes and the steepness of terminal and lateral scarps prove the viscosity to have been high, as usual.

The eastern part of the dome and much of the effluent trachyte still farther to the eastward were torn out by one or more great explosions, which developed an elliptical caldera, measuring 1500 meters by 1100 meters. In this depression later explosive eruptions built the steep

sided Peak, which is chiefly made up of basaltic tuff, ash, and breccia. The contact of this young cone with the caldera-wall of trachyte is shown in Plate XIV, *B*.

Along the Invalids Path from the main road to the Sanatorium, the young basaltic tuff, dipping 20–30 degrees away from Green Mountain summit, is seen to rest with strong unconformity on well-bedded, trachytic tuff. These sections indicate a somewhat prolonged interval of erosion between the two periods of explosion.

The Green Mountain trachyte is normal in preserving a marked fluidal structure. At and near the foot of a flow crossing the mountain road on the north side of the mountain, the banding dips 40–50 degrees southward, that is, in the direction from which the flow came. The shear-planes of the sliding magma were developed with this high upstream dip because of the specially high viscous resistance that was offered by the chilled, terminal part of the advancing flow. Such upturning of the shear-planes at the lower ends of the trachytic flows is very common in the island. (Compare Plates XV, *B* and XVII; Figure 8.) The flow is brecciated to a depth of three meters. It lacks ordinary vesiculation and also any systematic jointing. The floor phase has likewise been brecciated by movement.

Similar features characterize a very thick overflow of trachyte west of the Mountain Farm. This tongue occupied a radiating valley in the old, basaltic cone of Green Mountain, and is probably at least 150 meters thick at maximum. Its surface slope varies from ten to twenty-five degrees. In a cliff the brecciated floor-phase is well exposed; it measures five meters in thickness.

The trachyte of Middleton Peak ridge probably came from the Green Mountain vent, but the evidence is not perfectly clear.

Some of the Green Mountain outflows of trachyte inclose many angular, vesicular fragments of basalt, evidently derived from the walls or floor of the dome-vent.

Weather Post Dome. Most extensive of all the bodies of trachyte is that of the eastern part of Ascension, including Weather Post (alt. 1990 feet, 606 meters), White Hill, and the great flow north of the Devils Cauldron (Punchbowl). Possibly the composite mass is the product of eruption from a single center, but the general topography rather suggests that there were two chief eruptive centers. (See Plate XV, *A*.) One of these is under Weather Post; the other, under White Hill.

Near the most northerly point of the rim of Cricket Valley, the

Weather Post trachyte is seen to have welled out over a series of brown basaltic tuffs, dipping southwest, that is, away from the Weather Post-Cauldron massif. So far as it goes this observation lends color to the supposition that the Weather Post trachyte was erupted within the rim of an older basaltic crater or caldera — the case being like that illustrated at the Riding School, at Green Mountain, or at the analogous Cross Hill. A little farther to the southeast, thick basaltic flows are seen to dip at a low angle toward the Weather Post and apparently underlie a thick effluent tongue of the Weather Post trachyte. These flows may have come from Green Mountain, flooding the older crater-rim. On account of lacking exposures elsewhere the existence of the buried crater or caldera could not be definitely proved.

Among the causes of obscurity is a heavy mantle of coarse breccia, the débris from the Cricket Valley explosion, which covers much of the Weather Post dome and the wide trachyte flow on the north, hiding contacts.

At the head of that flow, which forms a rough, sloping plateau stretching nearly to Northeast Point is the Devils Cauldron, a remarkable explosion-crater or caldera (Plate XVI). The Cauldron is broadly elliptical, approximately 200 meters in length, 30 to 60 meters in depth, except on the northwest side, where the wall is only some ten meters high. The walls are everywhere steep, if not actually vertical. The trachytic débris from this explosion is deep on the surrounding trachyte. The fluidal structure of the trachyte in the walls of the Cauldron, developed as usual, shows planes of shear that are irregularly disposed, though often nearly vertical. They tend to strike parallel to the rim of the Cauldron, an indication that the Cauldron may possibly be the locus of a distinct dome-extrusion. Even in that case, however, the Cauldron dome might have been satellitic to the Weather Post dome.

That the Cauldron trachyte was erupted through older rock of basaltic habit is shown by its inclosure of many fragments of vesicular and trappean basalt or trachydolerite (probably the former). Here again a thick shell underlying the original surface of the trachyte has been brecciated by the flow to a more or less chaotic condition. Locally a few, small gas-pores were observed in that shell, but pronounced vesicularity in the ordinary sense was nowhere to be seen.

The well-bedded tuff and agglomerate on the rim of the Cauldron reaches 7 or more meters in thickness; on Weather Post the pyroclastic overburden has a maximum thickness approaching 40 meters. These

beds are chiefly composed of trachytic pumice, with some basaltic fragments, and many black to dark green, lustrous fragments of obsidian. The glass shows the common banding caused by devitrification in some layers, which, perhaps in consequence of local crystallization, are in some degree vesicular (operation of the "second boiling-point?").

On the southwest side, the Weather Post has certainly lost substance because of the powerful explosion at the so-called Cricket Valley (Figure 7). Probably there has been partial destruction of the dome by another major explosion on the eastern side, located in the deep depression between the Weather Post and the Powers Peak ridge. To this explosion may well be referred the trachytic débris, reaching a thick-

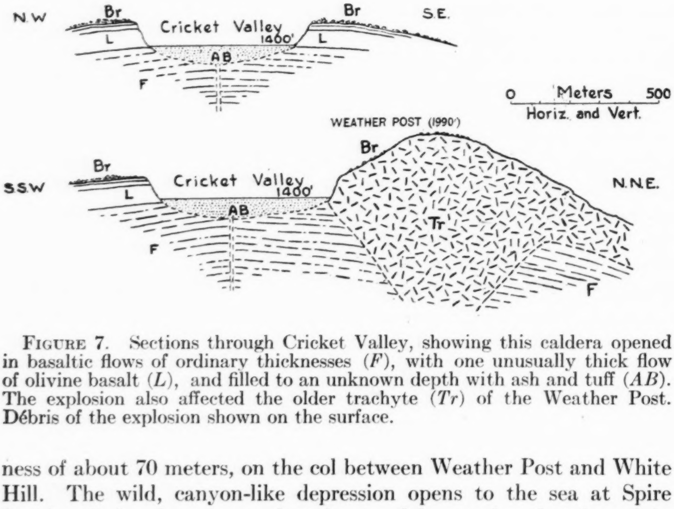


FIGURE 7. Sections through Cricket Valley, showing this caldera opened in basaltic flows of ordinary thicknesses (*F*), with one unusually thick flow of olivine basalt (*L*), and filled to an unknown depth with ash and tuff (*AB*). The explosion also affected the older trachyte (*Tr*) of the Weather Post. Débris of the explosion shown on the surface.

ness of about 70 meters, on the col between Weather Post and White Hill. The wild, canyon-like depression opens to the sea at Spire Beach. It has been somewhat deepened by erosion, but its origin as a deep caldera, rather than as primarily a valley of erosion, seems probable; further study on the point is needed.

The high cliffs bounding Weather Post on the south and southeast give exposures showing that the outflows from the dome, like those from the White Hill dome, range from 50 to 200 meters in thickness. They are separated by brecciated phases and thin beds of yellow, trachytic tuffs. On the southwest side of the Weather Post dome the

tuffs dip away from the dome at angles of 60–70 degrees, suggesting that they have been upturned by continued rise of the viscous dome-magma.

On the map (Plate I) two patches of basaltic rocks, at the shore northeast of Weather Post, are shown. They were not visited. From a distance the more northerly patch looks like a young lava flow which issued from an opening through the older, already solidified trachyte. The relation of the other patch is still more uncertain.

White Hill Dome. Petrographically the trachyte of the White Hill dome is like that of Weather Post, and, as above noted, sure evidence of any structural separation between the two massifs was not discovered.

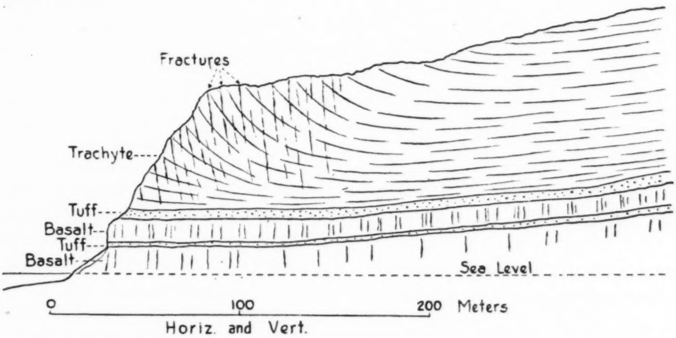


FIGURE 8. Longitudinal section through a thick flow of trachyte on the main island opposite Boatswain Bird islet; illustrating the common upturning of the trachyte flows near their lower extremities. Fractures due to tension.

On the walls of the grand amphitheatre opened above Spire Beach, the great thickness of the tongues apparently effluent from White Hill, and their separation by trachytic tuff and breccia, can be observed. The superficial appearance of the outflows is illustrated in Plate XVII, which serves also to show the form and structure of the trachytic flows in the whole island. The fluidal structure, the upturning of the shear-planes at the foot of the flow, here 30 to 70 meters thick, and the characteristic ragged, tensioned phase at the surface are all tolerably apparent in the photograph. Like many others, this flow is young enough not to have been greatly damaged by erosion.

The high cliffs southwest of Boatswain Bird islet exhibit a fine section through a White Hill outflow, illustrated in Figure 8. The

sketch had to be made from a distance, and no opportunity for a close study of the cliff was afforded; yet the drawing is believed to be correct in principle. The glacier-like upturning of the shear-planes downstream was particularly clear. Crossing these planes at high angles are joint-like fissures, shown in the drawing. They are presumably connected with the horizontal tensions developed in the steeply inclined flow as it gradually solidified.

At a point southwest of White Hill its effluent trachyte rests on a series of basaltic flows; the trachyte is charged with angular inclusions of vesicular and compact basalt. Hence the White Hill trachyte is younger than some of the basalts. Lack of exposures forbade a more specific reading of the relation of this trachyte to its foundation. At the contact just mentioned the floor-phase of the trachytic flow is well exposed. It has the usual brecciated appearance and also a special abundance of angular blocks of lustrous black obsidian, reaching as much as one meter to nearly two meters in diameter. The glass is much like that seen in the surface-phase of the trachyte at the Devils Cauldron, showing devitrified and vesicular bands with light gray and greenish tints.

Southeast Head Dome. The trachyte of Southeast Head has the topography of a flat dome. It is supposed to be an endogenous dome on a scale larger than the adjacent Little White Hill body and perhaps considerably widened in outcrop by overflows. Actual proof of that assumption is not to be had; the contacts of this trachyte with older rocks seem everywhere hidden from sight, under the sea or under younger lavas or ejectamenta. The hypothetical structure underground is given in the section on Plate I. The highest point of the monolithic body is charted as 479 feet (146 meters) above sea. Except on the western side the trachyte has been cliffed by the waves.

After the solidification of the dome it was split by a vertical fissure, which runs nearly due east and west through the summit of the dome. From the foot of White Hill the fissure was followed nearly 1200 meters. Mr. Hedley Cronk, superintendent of the Government Farm, on Green Mountain, states that the fissure continues to Bottle Point. At intervals throughout most of its length, dark gray to black, scoriaceous trachyandesitic lava flowed out over the pale gray trachyte in the form of broad and narrow tongues. The contrast of color between the trachyte and the younger flood is nothing short of spectacular. (See Plate XVIII.) The photograph fails to show fully the difference. The tracing of the photograph (reduced), given in the more diagrammatic Figure 3, expresses the relation of the two rocks perhaps more

vividly. The tongues of trachyandesite are thin and yet their final viscosity must have been great, for they hang on slopes as high as fifteen or twenty degrees. (See Plate VIII.)

Near the 479-foot point the fissure has been widened explosively and a double crater, from 30 to 50 meters in diameter, developed. On the crater-walls the pale gray, monolithic trachyte underlying the trachyandesitic flow is well seen. Evidently the last explosion, at least, followed the outflow of the trachyandesite. Between the two parts of the crater this rock forms a bridge, strongly sagged in the middle. A half dozen other and smaller vents of the central type have been formed along the fissure. From the western part of the fissure the trachyandesite ran southward, veneering the eastern foot of Little White Hill dome and the floor of the old crater in which that dome was extruded. One of the south-running flows, which flooded the valley between Little White Hill and Southeast Head has already been noted as showing terrace-like remnants left after the slumping of the chilled surface-phase because of subsurface draining. (See Figure 3.)

Visiting geologists should not fail to study the impressive features of the whole Southeast Head complex, and it is to be hoped that they will improve on the detail of mapping, which had to be done very sketchily in the time allowed during the writer's reconnaissance.

Cocoanut Bay and Pillar Bay Masses. No opportunity to sample these was given. From distant views the writer concluded that the bold cliffs at Cocoanut Bay are composed of trachyte, which probably forms a breached dome, partly buried under basaltic flows from Green Mountain. Whether the crater-like bay is due to wave-cutting or to explosion can not yet be stated. The nature and relations of the rocks at Pillar Bay are still more uncertain.

Boatswain Bird Islet. The topographic relations make it difficult to consider the picturesque monolith of this islet as connected with flows from either the Weather Post or the White Hill center. More probably it represents a strongly cliffed, independent dome, that issued from a special vent beneath (Plate XIX, *A*, *B*). Though the powerful waves have driven back the cliffs on all sides to considerable distances, the upper surface, now culminating about 323 feet (98 meters) above the sea, may not be very different from the original surface on this remnant of the dome. The perfect exposures on the vertical cliffs show the mass to be monolithic, cariously weathering, and altogether similar to the normal trachytes of the main island.

The rock has the usual weakness of the Ascension trachyte, so that the waves have been able to prolong the profiles of the vertical cliffs to depths of from ten to fifteen meters below low-water level. A fine natural bridge is a detail of the wave-cutting (Plate XX).

Pyroclastic Deposits.

The great explosions at Cricket Valley and the Devils Cauldron delivered projectiles reaching one to two meters in diameter, but in general the average pyroclastic deposit of the island is a rather coarse tuff or cindery ash. Many deposits are made of material wholly of basaltic habit. Other basaltic tuffs carry sporadic fragments of trachyte or trachytic pumice. In Green Mountain, and east and southeast thereof, beds of tuff and agglomerate, chiefly made of trachyte, are rather common. Large trappean projectiles which were thrown out of Cricket Valley caldera inclose trachytic xenoliths, evidently included when the basalt was molten.

The unweathered basaltic tuffs are variable in color, from black and dark gray to brown and deep red; all types weather to brown tints. The fresh trachytic tuffs are white, pale gray or pale greenish gray, weathering to light brown. Nowhere has weathering gone to the stage of important lateritization, such as is so general in Saint Helena. Ascension is too young for that.

Table I suggests the distribution of the principal bodies of pyroclastic material, but of course the finer débris of the more recent explosions veneers the surface far and wide, especially to leeward of each vent. Later winds and rains have redistributed the looser materials, which on the lower ground form long, local fans and stream-lines. The tuffs in situ are best exposed on windward slopes; on that of Green Mountain torrential rains have cut steep-walled gulches, from 20 to 60 meters deep, in the basaltic tuffs. The Devil's Ashpit is a deep, cirque-like gulch cut in The Peak tuff. The Peak itself has many radiating gorges and revett edges, developed by erosion in somewhat coarser material. The sand-like débris flooring Cricket Valley is the favorite home of thousands of brilliantly colored land-crabs, which have there found deep, loose material suitable for their burrowings.

Typical bread-crust bombs are rare in Ascension. Spindle-shaped bombs with smooth sides are fairly common; examples may be collected on Cross Hill, Sisters Peak, South Red Crater, and South Gannet Hill. Basing his thought on similar specimens which he col-

lected on Ascension, Darwin originated the true explanation of the form and structure of spindle-bombs.[5]

On the flanks of many tuff-breccia cones one finds scoriaceous blocks, a few decimeters in length, that roughly resemble spindle-bombs in shape. These appear, however, to have been formed in quite a different way — as tear-like exudations, rhythmically pinched off as small driblets of lava burrowed their way out to the air through the mobile fragmental deposits of the cones.

The trachytic tuffs are essentially composed of angular pieces of the ordinary, bubble-free trachyte, mixed with varying proportions of light pumice, in some places also with small fragments of black or deep green, lustrous obsidian. In most cases, if not in all, where the lower contacts of the thick outflows of massive trachyte can be seen, each flow is directly underlain by a bed of pumice-rich trachytic tuff. This rule suggests that the upper part of each ascending column of trachytic magma was exploded into the air before the main body rose high enough to cause lateral outflows or overflows.

Usually the trachytic tuffs are quite friable at the outcrop, but those widely exposed on the plain between Thistle Hill and the Bears Back are superficially hardened to a depth of two to five centimeters. This surface-shell is resonant under the hammer and recalls the irregular, silicified "veins" or interfaces of the trachytic domes and flows. The superficial silicification is here a phase of weathering under subarid conditions.

The Ascension tuffs show the centrifugal or outward dips and also centripetal or inverse dips, usual at vents with crater-rims. Successive beds may be unconformable, either because of erosion or because of explosion, taking place between the periods of pyroclastic action. In the second case the younger tuff may be seen to have been plastered on crater slopes at angles well above the angle of rest for even coarse, dry material; a good example was noted in the double crater opening near the foot of South Gannet Hill, south side.

Dikes.

Since neither deep erosion nor strong dislocations have affected the island, intrusive bodies visible at the surface are not to be expected. A half-dozen small dikes are the only bodies of the kind observed.

On the main road southwest of Cross Hill an irregular basaltic dike

---

[5] C. Darwin, Geological Observations, p. 42, 2d ed., London, 1876.

cuts slaggy breccia. With maximum width of about 25 centimeters, it strikes north 70 degrees east. Strong grooves were impressed on the dike-walls as the stiffening magma was forced past the rugosities of the breccia, east-northeastward, in a direction inclined 30 degrees from the vertical; the magma acted like a plastic solid, rather than like a purely viscous liquid.

A second, vertical, 15-centimeter dike of frothy, basaltic glass cuts a trappean flow at the north end of the old cliff at Southwest Bay.

The best exposed dike cuts basaltic ash on the western slope of Spoon Crater cone. This dike is vertical, is one to nearly two meters wide, and stands above the more easily eroded ash for a distance of about 150 meters. It strikes north 70 degrees west and may be connected with the Spoon Crater center.

A fourth vertical dike of basalt, with similar strike, cuts the base of a thick trachytic flow, 250 meters southwest of the top of Middleton Peak. This dike, more resistant to the weather than the trachyte, here brecciated by flow, stands up as a wall which is three to four meters high and about two meters wide. Three hundred meters to the westward a nearly parallel wall-dike of about the same width cuts trachytic tuff and breccia. In the absence of any other proof, these two dikes alone would show that some of the basaltic eruptions are younger than trachyte in Ascension.

Calcareous Deposits.

Though the physical conditions for the growth of coral reefs appear ideal at both Ascension and Saint Helena, neither island is fringed with reefs; the few species of corals now living along these shores are not reef-builders. The dominant and prevailing currents prevent colonization by larvae issuing from the reefs of the western Atlantic. On the other hand, both islands are in the "shadow" of Africa, so that west-bound currents cannot bring larvae from the Indo-Pacific region. There is no evidence that the conditions were essentially different at any time since the much older Saint Helena rose above sea-level.

Strong beaches of nearly pure calcareous sand have been formed in Clarence Bay and Southwest Bay. These are made up of fragments of shells, corals, and abundant calcareous algae, including Lithothamnion, a genus which seems to thrive as well as it does on a Pacific island. Darwin and Renard described these beaches, the former noting the advanced lithification of some of the deposits. (See Plate III, *B*.)

An older limestone at Southwest Bay represents a relatively ancient

storm-beach or dune-deposit, so lithified as to make building-stone, ringing under the hammer. In it the waves are now cutting low cliffs and it can be seen to extend outwards, well beyond the low-tide level of the sea. In this case the cementation looks like that which is so common in calcareous dune-sands within the tropics and caused by the evaporation of water, either sea-spray or rain-water.

At Georgetown the beach sands have been well cemented into "beach-rock," which is almost entirely confined to the vertical interval between high-water level and low-water level or a little deeper level. The calcium carbonate cementing the beach-rock came directly out of the sea-water; as noted elsewhere this mode of the lithification of beach sands in the tropical belt seems best explained by the action of alkaline carbonate which is generated during the decay of animal matter, specially concentrated in the sands and muds.[6]

The beach-rock at Georgetown is remarkably perforated by parallel worm-borings; the sand is most lithified along the walls of the bore-holes.

Faults.

Displacements by ordinary faulting are rare in Ascension. The only cases observed refer to faults in tuffs and tuff-breccias.

In the valley about 600 meters south of the 1187-foot point on Spoon Crater, a wet-weather stream has cut a fine gorge about 30 meters deep, where pyroclastic basaltic deposits are well exposed. Some 20 meters of deep red to brown tuff overlie one meter or more of light brown tuff, which itself rests on ten meters of dark gray tuff and breccia. This series dips to the southeast and seems to represent a relic of an old, elsewhere buried crater-rim, centering at or near the vertical axis of the Spoon Crater cone. The tuffs are cut by a complex of nearly vertical faults with throws ranging from three to six meters. The faults are probably all of the normal type.

Several faults cut the tuff-breccia series along the road up Green Mountain, near the 5-mile post and between the 1500-foot and 2000-foot contours. Both normal and reverse faults were found, with maximum observed throw of about two meters. All of these local displacements may be connected with the settling of the composite Green

---

6 R. A. Daly, Year Book No. 18, Carnegie Institution of Washington, for 1919, p. 192. See also the writer's "Geology of American Samoa" in Pub. No. 340 of the Carnegie Institution of Washington, 1924.

Mountain cone, either because of the compacting of its material under dead weight or because of internal magmatic movements. Possibly the reverse faults are due to the upthrust exerted by the stiff trachytic magma as it rose to form the great dome of the mountain. Along some of the fault-planes traversing black, basaltic tuff, pale brown trachytic sand has been injected in a manner suggestive of sandstone dikes (earthquake jars).

Petrography.

Renard, Prior, and Reinisch have indicated the main rock-types in Ascension. The collections of rocks studied by them were made by others, and in many instances neither the localities nor the field relations of the critical specimens could be stated with exactness. The sampling of 1921 showed that Darwin and the members of the Deutsche Südpolar Expedition had found the main volcanic species constituting the island. The following description is thus supplementary to the petrography already published by experts, whose essential results are summarized. Three new analyses of the trachytes are given, and also four new analyses of the basalts, of which the chemical nature had not been made sufficiently clear. The thin sections from the 1921 collection are 157 in number. Besides, the writer has studied a score of thin sections (without specified localities) kindly presented by Dr. J. S. Flett, Director of the Geological Survey of Great Britain.

Named in the order of decreasing volumetric importance, the volcanic rocks include: basalts, trachytes, trachydolerite, trachyandesite, and rhyolitic obsidian, the last being intimately associated with the trachytes. The dominant basalts will first be described, then the trachydolerites, trachytes, and obsidian; finally the granular, plutonic rocks which occur as fragments in tuffs and breccias or as xenoliths in the lavas.

Basalts.

Neither picritic nor limburgitic flows were seen in the island. The most mafic volcanic species collected is the abundant olivine basalt. It forms flows interbedded with, or overlying, flows of the even more common olivine-free or olivine-poor basalt. Some of the superficial, youngest flows, exemplified by the South Gannet flow and by the Bears Back flow or dome, are composed of olivine basalt. This kind of basalt forms rugged, tensioned flows as well as those so smooth as to

approximate the pahoehoe or ropy lava; as a rule they are not so scoriaceous as the olivine-free basalts.

Two typical fresh specimens were selected for analysis.

One of these, taken from the surface flow of the Southwest Bay group, at a point on the road, south 85 degrees east from McArthur Point and west of Dark Slope Crater, has been analyzed by Miss Helen E. Vassar, chemist in the Department of Mineralogy and Petrography at Harvard University. The flow is relatively smooth and has the "bouldery" habit above described. The rock is dark gray, with the usual appearance of common basalt. Fairly numerous phenocrysts of feldspar, reaching eight millimeters in length, are embedded in the compact base, which is moderately vesicular. Under the microscope the phenocrystic feldspar is seen to be acid bytownite, Ab_{25} An_{75}. Olivines, generally rounded and reaching maximum diameters of about one millimeter, are subordinate phenocrysts, composing about 12 per cent. of the rock by weight. The groundmass carries abundant pale green augite, much iron oxide, probably both magnetite and ilmenite, and apatite. Less than 5 per cent by weight is glass, darkened by skeleton crystals of iron oxide.

The analysis of this specimen (No. 2731) gave the results shown in column 1, Table II. In the Norm classification the analysis is that of an ornose, in the salfemane class and order, gallare; it is alkali-calcic and persodic, and near camptonose, the dosodic subrang of the same rang.

TABLE II.

BASALTS OF ASCENSION ISLAND.

	1	2	3	Norms.	1	2	3
SiO_2	47.69	48.64	52.87	Orthoclase	3.33	7.23	11.68
TiO_2	2.79	3.52	2.01	Albite	24.63	30.39	40.30
Al_2O_3	16.23	15.54	16.68	Anorthite	29.47	22.52	18.90
Fe_2O_3	2.20	5.31	4.54	Diopside	13.60	15.14	11.28
FeO	9.93	7.73	4.79	Hypersthene	8.83	9.14	6.05
MnO	.17	.17	.37	Olivine	10.48	.15	...
MgO	7.15	4.96	3.92	Magnetite	3.25	7.66	6.50
CaO	10.02	9.03	7.32	Ilmenite	5.32	6.69	3.80
Na_2O	2.87	3.60	4.63	Apatite	1.24	1.24	1.24
K_2O	.64	1.24	2.06	$CaCO_3$	.10	...	...
H_2O-	.09	.16	.40	Water	.28	.37	.70
H_2O+	.19	.18	.30				
P_2O_5	.59	.64	.52		100.53	100.53	100.45
CO_2	.04	.03	n.d.				
	100.60	100.75	100.41				
Sp. gr.	2.99	2.97	2.84				

1. Olivine basalt, surface flow of the Southwest group, specimen No. 2731; analysis by H. E. Vassar.
2. Olivine-poor basalt, flow, north wall of Cricket Valley, specimen No. 2850; analysis by H. E. Vassar.
3. Trachydoleritic basalt, flow from Mountain Red Hill, specimen No. 2839; analysis by E. G. Radley.

The second specimen, also analyzed by Miss Vassar, was taken near the 1600-foot contour in the north wall of Cricket Valley and about 300 meters due east of the 1884-foot point marked on the Admiralty chart. It represents a flow overlying the much thicker body of basalt exposed on the wall of the "valley" (Figure 7). The specimen is a compact, very slightly vesicular, fresh basalt, with a medium gray color. Occasional phenocrysts of feldspar, up to 5 millimeters in diameter, break the monotonous, trappean surface.

The phenocrysts are: bytownite, in some cases faintly zoned, with a medium labradorite on the exterior; and colorless, generally anhedral olivines, which make up about seven per cent. of the rock by weight.

The groundmass is a confused, granular, somewhat fluidal composite of labradorite, colorless, diopsidic augite, another pale green augite, iron oxide, and apatite.

The analysis of this specimen (No. 2850) is stated in column 2, Table II; the norm is that of a camptonose.

A specimen (No. 2839), probably not far from being representative of the most voluminous lavas of Ascension, has been analyzed by Mr. E. G. Radley, chemist of the Geological Survey of Great Britain, London. It was collected at a point 100 meters north of the summit of South Red Crater, from a flow that issued from Mountain Red Hill and wrapped around the cone of South Red Crater. The moderately vesicular, dark gray, compact rock shows rare phenocrysts of bytownite. Other rare phenocrysts of augite in stout prisms reaching one millimeter in length, are seen under the microscope. The groundmass is a composite of labradorite, very pale, greenish augites, magnetite, probably ilmenite, and apatite. Occasional, small grains of olivine represent an unimportant accessory. No glass was observed.

The specific gravity, 2.84, lower than that of either of the olivine basalts, is correlated with the less mafic nature of the Red Hill basalt.

The analysis of No. 2839 is given in column 3, Table II. The norm places it in the dosodic subrang andose, of the alkali-calcic rang andase, of the order germanare, of the dosalane class.

The rock is clearly on the border line between true basalt and trachydolerite, and may be called a trachydoleritic basalt.

Trachydolerites.

Hayes Hill, a low scoriaceous cone at the water-front of Georgetown, and a yet smaller cone of scoriae immediately north of the Landing Pier (Plate XXI, *A*, *B*) have each yielded a specimen analyzed by Reinisch, who has shown these lavas to be trachydolerites in the sense of the Rosenbusch classification.

Reinisch describes these specimens as "strongly vesicular, red-brown to brownish-black fragments of slag or bomb-fragments. . . . They carry in places a superficial layer of glass, 1-2 millimeters thick, and occasionally show small phenocrysts of plagioclase, though generally no mineral is macroscopically visible. . . . In thin section a groundmass of poorly transparent, dark brown glass, full of opaque flecks and minute grains of iron oxide, is seen to be charged with laths of plagio-

clase ranging from labradorite to andesine. . . . Neither pyroxene nor olivine appear." [7]

In a characteristic specimen of the Hayes Hill rock, No. 2784, the present writer has found some very small grains of augite and much rarer olivine; its specific gravity is 2.66. The specific gravity of a specimen, No. 2761, of the Landing Pier cone is 2.58. This rock is largely glass charged with granules of magnetite and larger crystals of medium labradorite and andesine, which are also the essential feldspars of No. 2784.

The analyses given by Reinisch are quoted in the following table (Table III).

TABLE III.

TRACHYDOLERITES OF ASCENSION ISLAND.

	1	2	Norms (Washington's Tables)	1	2
SiO_2	54.04	51.18	Orthoclase	20.57	20.57
TiO_2	.94	1.34	Albite	39.82	32.49
Al_2O_3	19.58	21.41	Anorthite	21.96	26.97
Fe_2O_3	5.09	4.61	Nephelite	. . .	3.41
FeO	3.75	3.32	Diopside	2.87	2.16
MgO	1.99	1.75	Hypersthene	3.43	. . .
CaO	5.54	6.56	Olivine	.90	2.38
Na_2O	4.70	4.72	Magnetite	7.42	6.73
K_2O	3.48	3.53	Ilmenite	1.82	2.58
H_2O	1.16	1.08	Apatite	.67	1.01
P_2O_5	.31	.48	Water	1.16	1.08
	100.58	99.98		100.62	99.38

1. Trachydolerite from Hayes Hill (cf. specimen No. 2784); analysis by R. Reinisch.
2. Trachydolerite from the Landing Pier cone (cf. specimen No. 2761); analysis by R. Reinisch.

As stated, both analyses fall in the dosodic subrang andose, of the alkali-calcic rang andase, of the perfelic order germanare, of the dosalane class. The accuracy of the alumina and magnesia determinations may well be questioned.

[7] R. Reinisch, Deutsche Südpolar-Expedition, Bd. 2, Geographie und Geologie, p. 652, 1912.

Reinisch describes basaltic trachydolerite "from two different beds at Cricket Valley." In these he found, besides phenocrystic plagioclase (labradorite to andesine), augite, and olivine, a groundmass composed of andesine, augite, olivine, and magnetite, with a cement of alkali-feldspar and anorthoclase. Mica and a barkevikitic hornblende and apatite are accessories.

He also refers to trachydolerite a lava which incloses fragments of trachyte which have been partly melted. This flow occurs nearly half way up the side of Green Mountain. Reinisch mentions trachydoleritic lapilli on The Farm, northeast slope of Green Mountain. In neither of these last two cases does he give evidence that the mafic rock is other than an ordinary basalt.

The monolithic ridge, culminating at the charted 193-foot point north of Cross Hill — a basaltic, pretrachyte product of eruptivity at the Cross Hill center — appears to carry a little alkali feldspar in the groundmass, which contains accessory biotite. The grain is so fine and the crystallization so confused that a precise determination of the alkali feldspar and of its amount have not been possible. Pending analysis this rock may be tentatively called a trachydoleritic basalt. The basaltic scoria and thin flows overlying the core trachyte of Cross Hill itself may be trachydoleritic; they have not been specially studied in thin section.

Andesite?

Renard, on page 58 of his report on the *Challenger* collection, mentions "certain rocks, much resembling basalts, which may be classed as andesites . . . met with in various parts of the island, particularly on Red Mountain." He referred the microlites of essential feldspar to andesine or oligoclase and the nominative mineral to bronzite. "The mineral identified as bronzite is always altered, and the decomposition shows itself by the deep red tint which clothes the section." He adds: "The red colour produced by alteration makes these little prisms resemble certain olivines, but the outlines of the sections and the elongated form of the prism do not confirm this supposition." (P. 59.) On the other hand, the present writer found in several sections of the basaltic rocks clear cases of olivine partly altered to a deep reddish-brown substance (probably iron-stained serpentine) and also fresh olivines so elongated as to simulate an orthorhombic pyroxene. To him it seems likely that the pseudomorphs described by Renard really represent olivine. Further study of this Red Mountain lava is needed. It was not sampled in 1921, and no true andesite was then elsewhere found in the island.

Trachyandesite.

The lava of the fissure-eruption at Southeast Head is of andesitic habit. Specimen No. 2864 was selected for analysis. It was taken from a tongue of the ragged flow on the western slope of the Southeast Head plateau, about 200 meters from the shore of Southeast Bay. It is a dark gray, in places almost black, vesicular rock, less scoriaceous than most of the flow. It contains a few xenoliths of a labradorite-augite lava, probably an olivine-free basalt.[8] Rare glints from micro-phenocrysts of feldspar form the only breaks in the dense groundmass, as seen with the unaided eye. The phenocrystic feldspar is largely andesine, Ab_{60} An_{30}, with occasional external shells of oligoclase-andesine. Other, untwinned, squarish phenocrysts have a very small optical angle and the extinctions of sodiferous orthoclase. A few small, automorphic, pale greenish phenocrysts of augite appear in thin section. The microcrystalline to cryptocrystalline groundmass is an aggregate of oligoclase-andesine, orthoclase, colorless to pale greenish diopside, euhedral to dust-like ilmenite or titaniferous magnetite, a little apatite, and interstitial glass. The proportion of glass is not easy to determine; it is estimated at from 10 to 15 per cent of the rock by weight.

The analysis of No. 2864, by Dr. H. S. Washington of the Geophysical Laboratory, Carnegie Institution of Washington, gave the results shown in column 1, Table IV; the norm places it in the dosodic subrang akerose, of the domalkalic rang monzonase, of the order germanare, of the dosalane class.

---

[8] The xenolithic character of this material was not recognized until it was studied in thin section; hence one reason for assuming in the field that the flow is an olivine-free basalt, as wrongly stated in the preliminary report (Geol. Mag., **59**, 149, 1922).

TABLE IV.

TRACHYANDESITE OF ASCENSION ISLAND.

	1	2		NORM OF NO. 1
SiO_2	58.00	57.72	Quartz	2.76
TiO_2	3.38	.37	Orthoclase	16.68
Al_2O_3	14.92	17.64	Albite	49.78
Fe_2O_3	1.73	4.47	Anorthite	5.84
FeO	5.78	2.78	Diopside	9.98
MnO	.11	.03	Hypersthene	4.55
MgO	2.23	1.01	Magnetite	2.55
CaO	4.50	4.36	Ilmenite	6.38
Na_2O	5.88	5.50	Apatite	1.55
K_2O	2.76	3.90	Water	.40
H_2O-	.09	...		
H_2O+	.31	1.65		100.47
P_2O_5	.71	.57		
	100.40	100.00		
Sp. gr.	2.68	...		

1. Flow from fissure, Southeast Head, specimen No. 2864; analysis by H. S. Washington.
2. Average of nine trachyandesites, reduced to 100 per cent.

Column 2 of Table IV gives the average analysis of nine trachyandesites noted in Rosenbusch's "Elemente der Gesteinslehre." The Southeast Head flow seems to be best classified as a trachyandesite.

TRACHYTES.

The study of about fifty new thin sections of specimens, collected from nearly all the different bodies of trachyte, has confirmed the impression, won in the field, that the Ascension trachytes are on the whole fairly uniform in chemical composition. Prior and Reinisch have already described most of the varieties. Without exception they contain strongly dominant alkaline feldspar, commonly about 80 per cent by weight, which is regularly soda-orthoclase with variable proportions of anorthoclase. The nominative minerals are aegirite, diopsidic augite, riebeckite, aenigmatite (cossyrite), and other brown amphiboles. Of these aegirite is by far the commonest constituent,

apparently failing only in certain trachytic projectiles found in the Green Mountain region. True, undoubted riebeckite seems to be confined to the dome-rock of Green Mountain, and to the trachytic tuffs and projectiles of that region. A closely allied amphibole in small amount characterizes the rock of "The Crags" dome. No mica has been discovered in any specimen.

This qualitative, mineralogical evidence of comparative uniformity is well matched by the chemical analyses. In addition to those published by Renard, Prior, and Reinisch, three new analyses are available. The description of the Ascension trachytes may well center around these analyses, old and new.

Trachyte of the Ragged Hill Dome. The specimen (No. 2855) collected at the top of this dome, but some meters below the initial surface, is of a fairly dark, greenish-gray color. It has the usual porosity of trachyte and is further normal in lacking bubble-vesicles of the kind common in basalts. The only phenocrysts are feldspars, from one to three millimeters in length and so abundant as to give the rock a somewhat syenitic look. Study of the thin section and of the rock-powder has showed that both soda-orthoclase, with extinction of eight degrees on (010), and anorthoclase are represented. The groundmass carries the same kinds of feldspar; considerable diopside, much aegirite, magmatically altered in large part to an opaque material resembling magnetite; deep greenish-brown to opaque material which suggests riebeckite or an allied amphibole; anhedra of magnetite, probably titaniferous. Neither quartz nor apatite was identified in the section, though both appear in the norm of the rock. No glass was seen.

The analysis of No. 2855, by Miss Vassar, gave the values shown in column 1, Table V. The analysis enters the dosodic subrang nordmarkose, of the peralkalic rang nordmarkase, of the perfelic order canadare, of the persalane class.

TABLE V.

TRACHYTES OF ASCENSION ISLAND.

	1	2	3	4	5
SiO_2	65.18	66.98	66.12	63.98	67.05
TiO_2	.44	.89	...	.28	.10
Al_2O_3	15.91	14.30	15.51	16.00	15.43
Fe_2O_3	4.41	3.85	3.27	2.57	3.25
FeO	.98	.33	.93	2.12	1.25
MnO	.17	.21	...	...	...
MgO	.10	.30	.17	.64	.16
CaO	.81	.83	1.05	1.58	1.06
Na_2O	6.24	6.76	6.31	6.45	6.12
K_2O	4.60	4.34	5.40	5.18	5.32
H_2O-	.45	.08	1.98	.61	.56
H_2O+	.53	.44			
P_2O_5	.08	.22	...	...	.04
BaO	...	.04	...	...	...
ZrO_2	...	.13	...	...	...
CO_2	.09	none	...	...	...
	99.99	99.70	100.74	99.41	100.34
Sp. gr.	2.64	2.54	...	...	...

1. Trachyte of Ragged Hill dome, specimen No. 2855; analysis by H. E. Vassar.
2. Trachyte of Southeast Head dome, specimen No. 2863; analysis by H. S. Washington. Special tests for S and Cr_2O_3 had negative results.
3. Trachyte from a point " north of Dark Slope crater "; analysis by R. Reinisch.
4. Trachyte of Cross Hill, quarry; analysis by R. Reinisch.
5. Trachyte from a point " half-way up Green Mountain "; analysis by R. Reinisch.

TABLE V.

NORMS OF TRACHYTES, Table V.

	1	2	3	4	5
Quartz	10.14	11.70	8.34	3.60	10.62
Orthoclase	27.24	25.58	31.69	30.58	31.14
Albite	52.92	49.26	49.78	53.45	49.78
Anorthite	1.67	...	...	...	...
Acmite	...	6.93	3.23	.92	1.39
Diopside	.43	1.73	.86	6.18	.86
Wollastonite	.12	...	1.74	.23	1.74
Titanite	...	.78	...	...	...
Ilmenite	.76	1.06	...	.61	.15
Magnetite	2.55	...	3.02	3.25	3.94
Hematite	2.72	1.44	...	...	...
Apatite	.31	.31	...	...	...
Zircon	...	.18	...	...	...
$CaCO_3$	.20	...	...	...	...
Water	.98	.52	1.98	.61	.56
	100.04	99.49	100.64[9]	99.43[9]	100.18[9]

Trachyte of Southeast Head. The third of the new analyses of trachyte was made from specimen No. 2863, collected at the western edge of the Southeast Head dome, about 100 meters from the shore at Southeast Bay. The rock is non-vesicular, compact, light brownish gray in color, and almost perfectly fresh. Rare glints of light betray the presence of phenocrysts of anorthoclase, generally less than one millimeter in length. The groundmass is a microcrystalline mass of soda-orthoclase, perhaps anorthoclase, micropoikilitic quartz, and colorless glass (the last about 8 per cent of the rock by weight), the whole sprinkled with a rather thin cloud of deeply colored aegirites in minute, corroded or skeletal forms, some magnetite, a few grains of colorless diopside, rare apatites, and very rare zircons. One small area of a black, opaque, moss-like mineral may be altered riebeckite.

The micropoikilitic quartz (nearly 10 per cent of the rock by weight) occurs in roundish, ragged individuals from 0.5 to 1.0 millimeter in diameter. It has precisely the same habit as the free quartz in the

9 The norms of Nos. 3, 4, and 5 are taken from Washington's Tables.

"silicious veins" soon to be described, and in the trachyte of Tutuila, Samoa, recently studied by the writer. Prior found it in the trachytes of Ascension, British East Africa, and the Aden peninsula.[10] Renard saw it in his specimens from Ascension, and, like Prior, doubted that the quartz originated in ordinary weathering. More probably it is of late-magmatic origin and was deposited by residual solutions of the magma after the crystallization of the other constituents.

The analysis of No. 2863, by Dr. H. S. Washington, is stated in column 2, Table V; its norm places it in the dosodic subrang kallerudose, of the peralkalic rang liparase, of the quardofelic order britannare, of the persalane class. The rock is a somewhat vitrophyric aegirite trachyte.

Riding School Trachyte. The glass-free, main part of the Riding School trachyte is a light gray, non-vesicular, minutely porous rock with rare phenocrysts of anorthoclase and soda-orthoclase up to three millimeters in length, and one-millimeter needles of aegirite. The microcrystalline to cryptocrystalline groundmass is essentially made up of the same minerals, together with a little aegirite-augite. A specimen from the northeastern overflow is free from quartz, but another, broken from the edge or rim of the basined dome itself, carries from five to ten per cent of micropoikilitic quartz by weight. A third thin section, from a typical "silicious vein" contains at least fifteen per cent of the micropoikilitic quartz. (See a later section on silicified interfaces.)

Reinisch (p. 649 of his paper) gives an analysis of a glass-rich diopside trachyte, collected at the northern foot of Dark Slope cone. At this locality the present writer found no trachyte in place and the specimen in question may be a transported fragment of the Riding School trachyte. Its analysis is quoted in column 3, Table V.

Reinisch found 68.31 per cent of silica and 2.47 per cent of water in a specimen of an "Alkali-Trachyt-Perlit," collected in the stream course north of the Riding School. He also gives analyses of a trachytic pumice from the foot of the Riding School cone, north side, and of a seal-red trachytic tuff from the southwest corner of the Riding School. These are quoted in Table VI.

---

10 G. T. Prior, Miner. Mag., **13**, 242, 255, 257, 259, 1903.

TABLE VI.

PUMICE AND TRACHYTIC TUFF FROM THE RIDING SCHOOL.

	1	2
SiO_2	63.02	55.10
Al_2O_3	15.75	18.56
Fe_2O_3	.52	6.80
FeO	3.15	.03
MgO	.38	.62
CaO	1.49	.70
Na_2O	6.11	3.17
K_2O	5.21	4.00
H_2O	4.83	8.30
Sol. in water	...	3.17
	100.46	100.45

Trachytes of the "Drip" Dome and the Mass at the Northwest Base of Thistle Hill. These are aegirite trachytes, hardly to be distinguished from the Riding School rock. The microphenocrysts include anorthoclase and rare aegirites. The groundmass carries essential soda-orthoclase, aegirite, and a diopsidic pyroxene. Quartz fails in the three sections made from the trachyte of the "Drip" dome; the Thistle Hill mass has a little micropoikilitic quartz. As usual the specially fine-grained phases are more sonorous under the hammer than the coarser phases, and even rival the "silicious veins" of the Riding School and other bodies, in this respect.

Trachyte of "The Crags" Dome. Beneath the pale brown, weathered shell, the fresh rock of "The Crags" dome is gray to fairly dark greenish-gray in color. It shows occasional phenocrysts of anorthoclase and soda-orthoclase, reaching maximum lengths of about four millimeters. The groundmass is essentially a microcrystalline aggregate of soda-orthoclase and aegirite, with subordinate diopsidic augite, magnetite, and much green to dark bluish gray, highly pleochroic amphibole of moss-like appearance, like that of riebeckite.

Trachyte of Cross Hill. This rock has a striking variety of color. At the quarry cut in the base of the western slope of the cone, the trachyte is a very pale gray, almost white. The same color character-

izes the outcrop 800 meters to the north and also much of the dome-rock on the northeastern slope of the hill. Light brownish and greenish phases are, however, common in the rock of the dome itself; on the path from Bates Cottage to the Wireless Station the tint is a decidedly dark greenish gray. The cause of this variation is not apparent; it can hardly be referred to weathering, since it is found in rock which is almost perfectly fresh.

The whitish rock of the quarry is speckled with very minute, dust-like grains of amphibole and ragged needles of aegirite-augite and aegirite. These can be distinguished only under the microscope, which also shows microphenocrysts of soda-orthoclase, anorthoclase, and rare individuals of a twinned feldspar, probably oligoclase-albite. The groundmass contains soda-orthoclase, possibly some anorthoclase, aegirite-augite, micropoikilitic quartz, and magnetite.

The very ragged, embayed amphibole has the pleochroic scheme: **a**, light yellowish green; **b**, deep brown to black; **c**, dark olive green. The extinction **c** : *c*, on the clinopinacoid is about 18 degrees; that on cleavage pieces is about 17 degrees. The optical angle is large. This amphibole thus resembles one described by Osann as occurring in the sanidinite of San Miguel.[11] It seems not to be the catoforite, reported by Reinisch from the quarry rock. Aenigmatite was not demonstrable by the present writer; Reinisch states it to occur in small amount.

Reinisch made an analysis of the quarry rock. His result is quoted in column 4, Table V. The norm of the analysis places it in the subrang nordmarkose, where the two analyses of the Riding School trachyte also fall.

The darker phase of the Cross Hill trachyte lacks essential amphibole; its groundmass bears a few deeply colored anhedra of an obscure brown mineral which may be aenigmatite.

Trachytes of Green Mountain. At least two types of trachytes are represented in Green Mountain: one with aegirite as the only essential mafic constituent; the other containing both aegirite and alkaline amphibole.

The aegirite trachyte, of the usual light gray to whitish tints, composes a thick flow outcropping on the road up the mountain at the 1400-foot contour. A similar variety composes the craggy mass, probably also an overflow from the central dome, the exposed part

---

11 See the Rosenbusch-Wülfing "Mikroskopische Physiographie," **1**, part 2, 237, 1905.

of which extends from the sanatorium to, and including, Monkey Rock north of the summit. These trachytes are free from quartz.

Amphibole-bearing phases seem to be quite abundant in the mountain. One of these, forming at the Valley Tank the trachytic rim of the caldera in which The Peak tuff-cone was built, has been specially studied. (See Plate XIV, *B*.) It is light gray and compact, with rare and small phenocrysts of soda-orthoclase and anorthoclase. The groundmass contains the same feldspars along with aegirite, aegirite-augite, and considerable riebeckite. Cossyrite (aenigmatite) was not identified.

The overflow exposed in a cliff-section 300 meters south-southwest of The Farm buildings has phenocrysts of soda-orthoclase, anorthoclase, and rare aegirites, in a groundmass containing, in addition, riebeckite, a diopside-like augite, many grains of an amphibole which may be aenigmatite, and micropoikilitic quartz. A dark brown to opaque, moss-like amphibole is probably magmatically altered riebeckite.

Reinisch reports aenigmatite-arfvedsonite trachyte from Green Mountain, taken at the level of the sanatorium; and again from the watercourse north of Donkeys Plain. He gives an analysis of a "catoforite-aenigmatite trachyte" collected half way up Green Mountain. See column 5, Table V. The analysis falls in the dosodic subrang, nordmarkose.

Large and small fragments of riebeckite trachyte are tolerably abundant in the breccias crossed by the road up Green Mountain and in the breccias on Middleton Peak ridge, a spur of the mountain. Many others are strewn over the floor of the valley followed by the Green Mountain road, westward and northwestward from Travellers Hill; many of these have been moved down the valley by freshets, but some, if not most of them, are projectiles from the explosive center of Green Mountain.

Three of the thin sections cut from these projectiles appear to contain, besides riebeckite, at least three other varieties of amphibole. All three have the same ragged, moss-like habit, as well as sensibly the single and double refraction, of the adjacent riebeckite. One of the varieties is strongly pleochroic: **a**, deep blue green; **b**, deep blue green to opaque; **c**, gray green. The extinction angle c : **c** is nearly zero. This mineral approximates true riebeckite. A second variety is highly pleochroic in brownish green and very deep brown colors. A third is nearly colorless, with a greenish cast. In long sections its extinction is nearly parallel to the cleavage, which is poorly developed

in all these amphiboles. The nearly colorless variety occurs isolated and also is seen to merge into the green amphibole. The former has all the appearance of being an iron-poor or iron-free analogue of riebeckite, as if it might be the chemical equivalent of the jadeite molecule among the sodic pyroxenes. With the material in hand this speculative suggestion cannot be properly tested.

The whole group of moss-amphiboles has the corroded look of minerals which have been subject to the reactions due to residual water-gas or other fluids of the late magmatic period. All of the dark-colored varieties, probably including many types intermediate between those described, have apparently been acted upon by water vapor or water gas, which has removed silica and concentrated iron oxides, rendering the remaining solid more or less opaque. This change parallels that so often observed in the case of aegirite.

Reinisch reports aenigmatite in all his specimens of amphibole trachyte. The present writer has had such difficulty in proving this mineral in the dense specimens of his own collection that he hesitates to list it in several instances where the mineral is suspected.

Quartz Trachytes.

Quartz Trachyte of White Hill Dome. Another mass from which no analysis has hitherto been reported is the great White Hill dome. A specimen (No. 2861) from the lower end of one of its outflows (Plate XVII) is highly fluidal or platy, with an alternation of thin, pale bluish gray and nearly white layers. This eutaxitic structure is connected with the varying degree of crystallization of the original glass. To the naked eye the rock is aphanitic throughout; the microscope shows microphenocrysts of soda-orthoclase. For the rest the rock is a layered composite of colorless glass, charged with minute, ragged needles of aegirite and skeleton-crystals of alkaline feldspar, chiefly soda-orthoclase. The only other crystallized minerals are magnetite, in minute specks, and about ten per cent of micropoikilitic quartz.

The analysis of No. 2861, by Mr. E. G. Radley, is given in column 1, Table VII. The analysis falls in the sodipotassic subrang liparose, of the peralkalic rang liparase, of the order britannare, of the persalane class.

Its chemical composition places the rock among the rhyolites. However, it is probable that the silica percentage has been increased by infiltration during the late magmatic period, and that the magma

was more nearly a typical trachyte than a typical rhyolite. To indicate the very close relation between this White Hill rock with the true trachytes of the island, the former may be called a quartz trachyte.

Trachytes of Little White Hill and Wig Hill. These have not been microscopically studied. In the field they appeared closely similar to the White Hill rock.

TABLE VII.

QUARTZ TRACHYTES (RHYOLITES) OF ASCENSION ISLAND.

	1	2	Norms	1	2
SiO_2	71.88	70.99	Quartz	23.40	25.86
TiO_2	.25	...	Orthoclase	28.36	13.90
Al_2O_3	12.85	14.84	Albite	38.78	50.30
Fe_2O_3	3.60	3.76	Anorthite	...	3.01
FeO	.05	.35	Corundum	...	1.33
MnO	.29	tr.	Acmite	5.08	...
MgO	.18	.14	Diopside	.86	...
CaO	.60	.60	Hypersthene	...	.40
Na_2O	5.32	5.94	$CaSiO_4$	.70	...
K_2O	4.78	2.40	Ilemite	.46	...
H_2O-	.18	.40	Magnetite	.46	1.16
H_2O+	.17		Hematite	1.66	3.04
P_2O_5	.05	...	Apatite	.09	...
			Water	.35	.40
	100.20	99.42			
Sp. gr.	2.58	...		100.20	99.40

1. Quartz trachyte, outflow from White Hill dome, specimen No. 2861; analysis by E. G. Radley.
2. "Augite trachyte" from Weather Post (reported by A. Renard, Petrology of Oceanic Islands, *Challenger* Reports, p. 52, 1889); analysis by Klement.

Weather Post-Devils Cauldron and Boatswain Bird Islet Trachytes. The trachyte continuously exposed from the top of Weather Post to the lower end of the great flow north of the Devils Cauldron seems to be a very homogeneous aegirite (-diopside) trachyte, bearing in the groundmass numerous ragged grains and short needles of black, opaque material which may represent magmatically altered

cossyrite as well as aegirite. The feldspars of phenocrysts and groundmass alike are soda-orthoclase with less important anorthoclase. Quartz does not appear in the three thin sections available, one from the northern flow and two from the rim of the Cauldron. The diopside phenocrysts are rare and bear thick mantles of aegirite

Renard (page 47 of his paper) gives an analysis of "augite trachyte" from Weather Post, column 2, Table VII. He explains the high silica by the infiltration of quartz, which is "probably of secondary origin." Taken as it stands, the analysis is that of the dosodic subrang, kallerudose, of the peralkalic rang, liparase, of the quardofelic order, britannare, of the persalane class.

The monolith of Boatswain Bird islet is an aegirite-diopside trachyte, poor in diopside, which is confined to the groundmass. Micropoikilitic quartz is rather abundant in the one thin section made from this rock; a little moss-like, black material may represent altered riebeckite or a closely allied variety of amphibole.

Silicified Interfaces ("Silicious Veins") in the Trachytes.

The weathered surface of practically every body of trachyte in the island is locally roughened with prominent, intersecting, rib-like ridges (Plates VI and XIII). They are spaced at intervals varying from a few centimeters to one or more meters. Intersections occur at intervals of the same orders of magnitude. Where vertical, the ribs usually project some centimeters or a few decimeters. Those more nearly parallel to the general surface of the ledge often form hard caps, standing on round, more or less slender necks composed of the weaker, more normal trachyte. The weathering of each composite may be described as carious, on a large scale.

Darwin's attention was actively drawn to the problem of these projecting ribs, which he called veins. His account of them is excellent and worth quoting: "They contain crystals of glassy feldspar, black microscopical specks and little dark stains, precisely as in the surrounding rock; but the basis is very different, being exceedingly hard, compact, somewhat brittle, and of rather less easy fusibility. The veins vary much, and suddenly, from the tenth of an inch to one inch in thickness; they often thin out, not only on their edges, but in their central parts, thus leaving round, irregular apertures; their surfaces are rugged. They are inclined at every possible angle with the horizon, or are horizontal; they are generally curvilinear, and

often interbranch one with another From their hardness they withstand weathering, and projecting two or three feet above the ground, they occasionally extend some yards in length; these plate-like veins, when struck, emit a sound, almost like that of a drum, and they may be distinctly seen to vibrate; their fragments, which are strewed on the ground, clatter like pieces of iron when knocked against each other. They often assume the most singular forms; I saw a pedestal of the earthy trachyte, covered by a hemispherical portion of a vein, like a great umbrella, sufficiently large to shelter two persons. I have never met with, or seen described, any veins like these; but in form they resemble the ferruginous seams, due to some process of segregation, occurring not uncommonly in sandstones — for instance, in the New Red sandstone of England. Numerous veins of jasper and of siliceous sinter, occurring on the summit of this same hill, show that there has been some abundant source of silica, and as these plate-like veins differ from the trachyte only in their greater hardness, brittleness, and less easy fusibility, it appears probable that their origin is due to the segregation or infiltration of silicious matter, in the same manner as happens with the oxides of iron in many sedimentary rocks."[12]

Largely because of its sonority when struck with a hammer, Renard (page 60 of his paper) assumed that one of his specimens, collected by Dr. Maclean of the *Challenger* Expedition staff, and labelled "piece of clinkers," represented one of these "veins." The locality of the specimen, Southwest Bay, and its mineralogical composition show, however, that this is a normal, clinkery phase of the basaltic lava and has nothing to do with the hard "veins" in the trachytes.

Thin sections of the "veins" show, in fact, that Darwin was right in attributing them to the local silicification of the normal trachyte. The introduced silica is always quartz in micropoikilitic form, exactly like that seen in some of the more normal trachytes. The proportion of quartz by weight in the "veins" has been roughly estimated as from 15 to 25 per cent, or from five to ten or more times the amount found in the rest of the rock mass.

The free silica has not been introduced during the simple weathering of the trachyte; its formation is most probably to be ascribed to late-magmatic action. After the effluent trachyte came to rest, its glass cooled and crystallized, with the generation of tensions analogous to those causing columnar jointing in lavas. The magmatic steam escaped, preferably along the actual or potential partings so developed,

12 C. Darwin, Geological Observations, pp. 51–52, 2d ed., London, 1876.

and from the volatile solution the quartz was precipitated. A little hematite seems to have been simultaneously formed, giving the characteristic reddish tint, often seen on the "veins." The silicified sheets are not true veins; they are merely parts of the trachyte modified by fluids, presumably gaseous solutions, migrating along interfaces of the trachyte. Any fissures along the interfaces seem seldom to have had widths greater than a fraction of a millimeter.

It is not unreasonable to assume that the gaseous solutions responsible for the silicification described were the same as those which have so notably affected the pyroxenes and amphiboles of the normal trachytes. The conversion of much or all of the aegirite or riebeckite into pseudomorphs of iron oxides and other substances has clearly been accompanied by the leaching-out of silica from the original minerals; its late deposition, as micropoikilitic quartz, at some distance in the rock might readily be expected.

Obsidians.

The obsidians of Ascension occur as projectiles and as chilled, surface and floor phases of the trachytic flows. Independent bodies of glass of large size, either extrusive or intrusive, were not found. Whether in place or in the form of projectiles, the observed, non-pumiceous glass is confined to the region occupied by the greater domes of trachyte, including the Riding School, Green Mountain, Weather Post-Devils Cauldron, and White Hill. The projectiles were seen to be particularly abundant in the trachytic breccias and tuffs underlying the trachytic flows The largest individual bodies of glass are those constituting parts of the floor phases of the flows. These phases are composed of alternating glassy and lithoidal layers in the usual eutaxitic combination, obviously a flow-structure.

In his "Geological Observations" Darwin devoted half of his chapter on Ascension Island to a minute description of the massive, laminated, and spherulitic obsidians. His masterly account is accessible to every reader and need not be repeated.

The massive obsidian is lustrous black to greenish black by reflected light, and dark green by light transmitted through splinters. In every thin section the glass is charged with many slender, often line-like needles of diopsidic, green augite, with which, in some sections much rarer, small microphenocrysts of soda-orthoclase are associated.

Renard has quoted the essential facts from Darwin's description and has supplied the analysis of a Green Mountain specimen, given in column 1 of Table VIII. Column 2 gives an analysis, by Reinisch, of a "Rhyolithobsidian," collected in the stream-course north of the Riding School. Columns 3 and 4 give, respectively, Reinisch's determinations of silica and water in a spherulitic "Rhyolithobsidian" from the outer mantle of the Riding School, and in "Obsidianknollen" collected on the "Kegelmantel" of Green Mountain.

TABLE VIII.

	1	2	3	4
SiO_2	72.71	71.42	69.70	65.59
Al_2O_3	12.80	14.09	...	...
Fe_2O_3	2.64	1.41	...	...
FeO	1.48	2.32	...	...
MnO	Tr.	...	...	...
MgO	0.10	0.08	...	...
CaO	0.58	0.80	...	...
Na_2O	6.50	6.01	...	...
K_2O	3.87	3.52	...	...
H_2O	0.48	0.85	0.94	0.87
	101.16	100.50		

Washington's Tables states the norms of 1 and 2, as follows:

	1	2
Quartz	21.54	20.58
Orthoclase	22.80	20.57
Albite	44.02	50.83
Anorthite	...	1.11
Acmite	7.39	...
Sodium metasilicate	0.61	...
Diopside	2.45	2.45
Hypersthene	1.78	1.95
Magnetite	...	2.09
Water	0.48	0.85
	101.07	100.43

Analyses 1 and 2 both fall in the dosodic subrang, kallerudose.

The specific gravity of a 20-centimeter, non-vesicular projectile, composed of very homogeneous black obsidian, containing about two per cent of augite needles, was found to be 2.415 at 20° C. Tilley obtained the density (grams per cubic centimeter) of 2.435 for a specimen of Ascension obsidian, locality being unspecified.[13]

Xenoliths and Projectiles of Plutonic-rock Types.

Even before the year 1828 members of the naval garrison of Ascension had observed pieces of granite among the volcanic projectiles of the island. The first published account of these seems to be due to the surgeon, Webster. On page 316 of his entertaining book occurs the following passage: "There are various specimens of fragments of granite, and other primitive rocks, found scattered indiscriminately among the lava, or lying in the beds of cinders, and they bear more or less the marks of the action of fire. Some of the species of granite are very perfect and complete; others are semi-calcined and brittle. The quartz rock appears converted into a mass like red sandstone. Argillaceous schist, and graywacke, and syenite are likewise found."[14] Neither schist nor graywacke were discovered by the present writer nor, apparently, by any other visitor to the island since Webster's time; hence it seems likely that Webster mistook certain tuffs for the rocks in question.

Darwin's later account of the granitic fragments is readily accessible in his "Geological Observations"; it is summarized, and new data resulting from microscopic study have been added, by Renard in his paper, already quoted.

Darwin collected his granitic specimens "in the neighbourhood of Green Mountain." Granitic projectiles are relatively abundant in the basaltic tuffs crossed by the switch-back road to the summit, between the 1350-foot and 1500-foot contours; that is, below the 5-mile post on the road. Artificial cuttings furnish good exposures of these tuffs, from which the present writer took a number of angular to subangular, coarsely granular fragments, mixed with larger blocks of porphyritic trachyte. The former range from two to ten centimeters in diameter.

---

13 C. E. Tilley, Mineralog. Mag., **19**, 275, 1922.

14 W. H. B. Webster, Narrative of a Voyage to the Southern Atlantic Ocean in the years 1828, 1829, 1830, performed in H. M. Sloop *Chanticleer*, **2**, 316, London, 1834.

One specimen is light gray to white, speckled with many small lustrous black amphiboles. The grain is medium to fine. Under the microscope the rock is seen to be made up of microperthite, soda-orthoclase (a little oligoclase in one thin section), quartz, and a highly pleochroic amphibole. Magnetite, apatite, and rare zircons are accessories. The quartz occurs as isolated, interstitial grains and also to a considerable extent in micrographic and also poikilitic relations to the feldspars. The amphibole has enormous absorption, with the following scheme of colors for sections of the usual thickness: **a**, yellowish brown; **b**, very deep brown to opaque black; **c**, deep brown. **b** > **c** > **a**. The colors and double refraction recall aenigmatite, but the extinctions measured on cleavage plates (110) are never more than two degrees. The absorption scheme and the abnormal extinction angle may possibly be connected with the reheating and oxidation of a normal hornblende after the granite became immersed in the basaltic magma in depth. C. Schneider and M. Belowsky have induced both kinds of change in iron-rich amphibole by artificial heating [15]

At the same locality other specimens of hornblende granite, pinker in color and less charged with micropegmatite, were also found.

On the trail which contours The Peak on the north side, specimens of augite-hornblende-quartz syenite, olivine-poor gabbro, and typical augite-biotite diorite were collected from the basaltic tuff of The Peak. The quartz syenite carries a small amount of oligoclase; like all the other syenites, it is nearly a quartz-poor equivalent of the granite above described.

The trachytic tuffs of Green Mountain likewise yielded many angular fragments of granular rocks, especially on the southern slope of the Middleton Peak ridge. The largest fragment collected measures about 10 centimeters in diameter. Microscopic examination showed representatives of the following types:

1. Alkaline hornblende-biotite granite; light pinkish gray, medium-grained, rich in microperthite.
2. Brownish to pinkish gray, strongly miarolitic hornblende syenite with accessory quartz — a quartz syenite.
3. Pinkish gray augite-hornblende-quartz syenite, transitional to granite.

---

[15] See H. Rosenbusch and E. A. Wülfing, Mikroskopische Physiographie der petrographisch wichtigen Mineralien, 4te. Auflage, Bd. 1, 2te Hälfte, p. 234, Stuttgart, 1905.

4. Light greenish gray, medium-grained, salic diorite, transitional to monzonite; altered; probably carried much original augite and biotite, now represented by uralite and chlorite.
5. Light brownish gray, mottled, sugary, miarolitic augite-hornblende diorite.
6. Typical olivine gabbro.
7. Typical olivine-free gabbro.
8. An unusual olivine-free gabbro, made up of highly automorphic augite and labradorite, embedded in an opaque black cement, which is almost unaffected by a magnet and is probably ilmenite.
9. Typical coarse-grained wehrlite.

Granitic boulders of the kinds above described occur in the gravel streams of the main valleys north of Green Mountain.

In the massive trachyte of "The Crags" dome a single, angular inclusion of granite was found. It measured five centimeters in greatest diameter. This rock closely resembles the alkaline hornblende granite from the basaltic tuffs of Green Mountain. The feldspars are microperthite and orthoclase, the latter being surrounded by thick shells of soda-orthoclase. The amphibole is apparently identical with the abnormal variety, just described, in the projectile from the basaltic tuffs of Green Mountain. Brown biotite is a rare accessory in the xenolith.

Many angular and subangular xenoliths of gabbro were discovered in the scoriaceous flows of basalt which issued from Dark Slope crater. These fragments of plutonic character range from a few centimeters to 50 centimeters or more in diameter. All are dark gray to deep green-gray, medium-grained to rather coarse-grained even for gabbros, and more or less friable. This weakness of the material is not due to weathering, but doubtless to the loosening of the original fabric by the second heating. Probably more than half the xenoliths seen are typical olivine gabbros. Also numerous are olivine-free gabbros, which differ among themselves, some bearing essential diallage, others a diopsidic augite without the diallagic parting, and still others containing both kinds of pyroxene. Throughout the series the feldspar averages close to bytownite, $Ab_{25}An_{75}$, with but small variations from the mean.

The specimens from the Dark Slope cone were collected in the failing light of the dusk. Several very friable inclusions were then, under the poor conditions for observation, thought to be granitic. That

conclusion was stated in the writer's preliminary account of his visit to the island.[16] When later the rock collection was unpacked, it was found that no quartz-bearing specimen from Dark Slope was included. Hence it is now doubtful that granitic xenoliths actually occur in these basaltic flows.

The whole list of granular projectiles and xenoliths in the writer's collection thus includes:

1. Alkaline amphibole granite; both with and without micropegmatite.
2. Alkaline hornblende-biotite granite.
3. Pyroxene-hornblende-quartz syenite.
4. Hornblende syenite, verging on quartz syenite.
5. Monzonitic diorite.
6. Typical augite-biotite diorite.
7. Typical augite-hornblende diorite.
8. Augite gabbro.
9. Abnormal augite gabbro with ilmenitic mesostasis (free from olivine).
10. Typical olivine gabbro.
11. Typical olivine-free gabbro.
12. Typical wehrlite (peridotite).

Renard describes the following additional types among the projectiles studied by him:

13. Biotite granite, bearing some micropegmatite.
14. Biotite-bearing "diabase."
15. Enstatite-bearing, olivine-free gabbro.

All of the salic fragments are fritted and brittle, and some of them carry small, irregular ribbons and droplets of brown glass, showing incipient fusion. In most cases the essential minerals are murky with fluid and glassy inclusions; cleavages are unusually well developed, probably because of the reheating.

If any of the granular rocks were notably strained, or gneissic through metamorphism in the solid state, one could be reasonably certain that those fragments were derived from an older terrane underlying the great cone of Ascension, at a depth of 2500 or more meters below sea-level. However, the visible evidences of strain — undulose

---

16 See Geol. Mag., **59**, 149, 1922.

extinction and moderate fracturing of the minerals, especially quartz — are of the kinds expected because of heating in the volcanic vents. Hence it is not easy to decide the question whether or not all of the granular rocks are deep-seated phases of the magma represented in the exposed part of the Ascension cone. The gabbroid, dioritic, and wehrlitic xenoliths and projectiles are most readily explained as plutonic phases or differentiates of that magma. The problem of the more salic fragments is more widely open.

The granites and syenites are mineralogically and chemically allied, all of them being of alkaline types and usually rich in microperthite or soda-bearing potash feldspar. Their consanguinity is further suggested by an essential mineral in common, hornblende, and by the occurrence of transitional varieties, the quartz syenites. Probably, therefore, all these salic fragments originated in a single mass, or a number of syngenetic masses, of plutonic rock. All of them are chemically and mineralogically quite different from the trachytes and quartz-trachytes (rhyolites) of the island, and it is hard to believe that the granites and syenites are merely deep-seated differentiates, syngenetic with those salic phases of the surface lavas. Though many coarse-grained fragments of aegirite-bearing, porphyritic trachyte, approaching syenite porphyry, accompany the granular fragments, not one represents a transition between the true syenite and the trachyte. On the whole it seems most probable that the granitic and syenitic fragments were derived from an older terrane on which the Ascension cone rests.

If the granite is a "continental rock," as it appears to be, the early discovery of these quartz-bearing projectiles at Green Mountain, corroborated by Darwin and later visitors to the island, is obviously important. That discovery has been thought to support the views of those who believe the Atlantic basin was formed by the foundering of a vast block of a primitive continent. On the other hand, if granitic, "continental" terranes enter into the composition of the mid-Atlantic swell, on which Ascension is built, the swell itself might with as much plausibility be regarded as the zone of parting and crustal readjustment when America and Eurasia-Africa slid away from each other. Truly this newer explanation of the Atlantic basin faces difficulties, but they seem to be no more portentous than those facing the older hypothesis, which, for example, has never been brought into agreement with the principle of isostasy.

Quite recently Lacroix has published an account of the discovery of biotite granite, quartz-aegirite syenite, and nephelite syenite,

occurring as pebbles and larger detached blocks on Kerguelen Island.[17] This island, dominantly basaltic but bearing some phonolite, is situated on the site of Gondwanaland in the open Indian ocean — a position analogous to that of Ascension in relation to the former land connection between Africa and South America. The lavas of Kerguelen, in which no quartz-bearing phases have been described, appear to be chemically more like those of Saint Helena than the lavas of Ascension, but the parallel between Ascension and Kerguelen is sufficiently close to suggest that the origin of the quartzose, granular rocks is in each case connected with those events that have led to the formation of a relatively young ocean basin.

Order of Eruption.

In many instances the trachytic bodies have been proved to rest upon, or to have penetrated, older rocks of basaltic habit. That this is a perfectly general relation is reasonably inferred from: (1) the stratigraphic facts ascertained at Green Mountain, Riding School, the southeast end of Sisters Peak group of cones, Weather Post, White Hill, and Little White Hill; and (2) from the presence of basaltic xenoliths in the trachytes of Cross Hill, Riding School, Green Mountain, White Hill, Devils Cauldron, the "Drip" dome, and Ragged Hill.

On the other hand, the trachytes are overlain by, and thus older than, some of the rocks of basaltic habit. Among the specially clear examples are those at Green Mountain (The Peak basaltic tuff built up on a trachytic wreck), Cross Hill (basaltic tuff and flows resting on a trachytic dome), the "Drip" dome (largely covered by basaltic tuff and lapilli), and Ragged Hill (dome flooded at its base by basalt flows). The young basaltic tuffs of Cross Hill, The Peak, and Green Mountain in general carry fragments of trachyte.

All of the visible bodies of trachyte were obviously erupted at a very late stage of the growth of the Ascension composite cone, of which at least 95 per cent is below sea-level. The absolute lengths of time separating the trachytic eruptions cannot be very great. Possibly, indeed, the visible trachytes were all generated during one, comparatively brief period in the history of the Ascension magma. Their differentiation may thus have been quite contemporaneous, though the actual eruptions may not have been contemporaneous. Definite proof of difference of age among the trachytes could not be found

[17] A. Lacroix, Comptes Rendus, **179**, 113, 1924.

except in the fact that some of the domes appear to be more weathered than others. Allowing for this, one may still be justified in assuming that there may have been a distinct trachytic period in the evolution of the Ascension composite. The small amount of rhyolitic magma demonstrated in the island is clearly contemporaneous with the accompanying and much more voluminous trachytes.

As already remarked, the xenoliths and tuff-fragments of plutonic rocks are doubtless of different ages. The gabbro and peridotitic xenoliths of the Dark Slope flows are most simply regarded as relatively young, deep-seated phases of the basaltic magma which has built up so great a part of the Ascension cone. The granitic fragments of the tuffs are considered to be derivatives from the basement on which that cone rests, and the same may be assumed with some probability in the case of the syenitic fragments, though one cannot definitely exclude the hypothesis that some of these represent deep-seated phases of the young trachytic magma.

The sequence of the volcanic rocks in Ascension is like that registered in many other regions where alkaline trachytes have been found. It is worth while to review some examples.

1. Glangeaud's notable monograph on the puys of the Auvergne conveniently summarizes the observations of many masters, including his own observations, on those celebrated volcanoes. In many respects the classic French group is like the assemblage of vents and masses in Ascension. There too basalt flows antedate the trachytic eruptions. At each of four of the puys extrusion of trachytic lava was followed by extrusion of younger basaltic lava. At the Puy des Gouttes pyroclastic beds of trachytic and basaltic lava material alternate.[18]

2. An analogy is seen in the Velay, where the trachyte of Queyrières forms flows between older basalt and younger, black andesite.[19]

3. In the Cantal the order of eruption is from basalt, through trachyte, to andesite, and, finally, flooding basalt.[20]

4. According to Harker the effusive trachyte of Skye has a stratigraphic position in the midst of the great Tertiary series of basalts of that island.[21]

5. In the German Westerwald the sequence, from oldest to youngest is: basalt, trachyte, andesite, basalt.[22]

---

[18] P. Glangeaud, Bull. 135, Service carte géol. de la France, pp. 47–48, 1913.
[19] P. Termier, Bull. 13, Service carte géol. de la France, p. 6, 1890.
[20] M. Boule, Livret-guide, VIII^{e} Congrès géol. internat., part 10, Paris, 1900.
[21] A. Harker, Tertiary Igneous Rocks of Skye, pp. 56–57, Glasgow, 1904.
[22] G. Angelbis, Jahrb. preuss. geol. Landesanst., **3**, xlv, 1883.

6. According to Holmes the Tertiary lavas of the Sanhuti district of Mozambique were erupted in the following order: ordinary basalt, trachytoid phonolite, picritic basalt.[23] The sequence is thus analogous with the other cases.

7. The very extensive eruptions of Somali Land occur in the following order: oldest, porphyritic basalts; then pantellerites and soda-rich rhyolites; youngest, doleritic basalts.[24]

8. In central Madagascar eruptions of basalt precede and follow those of trachyte and phonolitic trachyte.[25]

9. The Cenozoic lavas of the state of Victoria, Australia, were erupted in the order: basalt, trachyte, basalt.[26]

10. Süssmilch states that the late-Tertiary phonolites, alkaline trachytes and allied types of New South Wales were preceded and followed by flows of normal basalt.[27]

Petrology.

Average Composition of the Types of Lava; some Comparisons. For convenience in discussing the genetic relations of the Ascension rocks the available chemical analyses have been assembled in Tables IX and X.

---

[23] A. Holmes, Quart. Jour. Geol. Soc., **72**, 231, 1917.
[24] H. Arsandaux, L'étude des roches alcalines de l'Est-Africain, p. 16, Paris, 1906.
[25] A. Lacroix, Comptes Rendus, Acad. des Sciences, **154**, 315–316, 476, 1912.
[26] E. W. Skeats, Presidential Address, Australian Assoc. Adv. Science, **12**, 173, 1909.
[27] C. A. Süssmilch, Presidential Address, Jour. Roy. Soc. New South Wales, **57**, 36, 1923.

TABLE IX.

Analyses of Femic Rocks of Ascension Island.

	1	2	3	4	5	6
SiO_2	47.69	48.64	52.87	51.18	54.04	58.00
TiO_2	2.79	3.52	2.01	1.34	0.94	3.38
Al_2O_3	16.23	15.54	16.68	21.41	19.58	14.92
Fe_2O_3	2.20	5.31	4.54	4.61	5.09	1.73
FeO	9.93	7.73	4.79	3.32	3.75	5.78
MnO	0.17	0.17	0.37	...	...	0.11
MgO	7.15	4.96	3.92	1.75	1.99	2.23
CaO	10.02	9.03	7.32	6.56	5.54	4.50
Na_2O	2.87	3.60	4.63	4.72	4.70	5.88
K_2O	0.64	1.24	2.06	3.53	3.48	2.76
H_2O-	0.09	0.16	0.40	1.08	1.16	0.09
H_2O+	0.19	0.18	0.30			0.31
P_2O_5	0.59	0.64	0.52	0.48	0.31	0.71
CO_2	0.04	0.03	...	...	...	...
	100.60	100.75	100.41	99.98	100.58	100.40
Sp. gr.	2.99	2.97	2.84	(2.58)[28]	(2.66)[28]	2.68

1. Olivine basalt, flow of the Southwest Bay group (Vassar, analyst).
2. Olivine basalt, Cricket Valley (Vassar, analyst).
3. Trachydoleritic basalt, South Red Crater (Radley, analyst).
4. Trachydolerite, cone at Landing Pier, Georgetown (Reinisch, analyst).
5. Trachydolerite, Hayes Hill (Reinisch, analyst).
6. Trachyandesite, fissure-eruption at Southeast Head (Washington, analyst).

[28] Determined from specimens collected by the writer and not from those analyzed.

TABLE X.

Analyses of Salic Rocks of Ascension Island.

	1	2	3	4	5	6	7	8	9	10	11
SiO_2	65.18	66.98	63.98	67.05	66.12	71.88	70.99	63.02	68.31	55.10	72.71
TiO_2	0.44	0.89	0.28	0.10	...	0.25	...	...	...	...	...
Al_2O_3	15.91	14.30	16.00	15.43	15.51	12.85	14.84	15.75	...	18.56	12.80
Fe_2O_3	4.41	3.85	2.57	3.25	3.27	3.60	3.76	0.52	...	6.80	2.64
FeO	0.98	0.33	2.12	1.25	0.93	0.05	0.35	3.15	...	0.03	1.48
MnO	0.17	0.21	...	...	...	0.29	Tr.	...	...	...	Tr.
MgO	0.10	0.30	0.64	0.16	0.17	0.18	0.14	0.38	...	0.62	0.10
CaO	0.81	0.83	1.58	1.06	1.05	0.60	0.60	1.49	...	0.70	0.58
Na_2O	6.24	6.76	6.45	6.12	6.31	5.32	5.94	6.11	...	3.17	6.50
K_2O	4.60	4.34	5.18	5.32	5.40	4.78	2.40	5.21	...	4.00	3.87
H_2O-	0.45	0.08				0.18					
H_2O+	0.53	0.44	0.61	0.56	1.98	0.17	0.40	4.83	2.47	8.30	0.48
CO_2	0.09	...	...	...	...	...	...	...	...	...	...
P_2O_5	0.08	0.22	...	0.04	...	0.05	...	...	...	...	...
BaO	...	0.04	...	...	...	...	...	...	...	...	...
ZrO_2	...	0.13	...	...	...	...	...	...	...	...	...
	99.99	99.70	99.41	100.34	100.74	100.20	99.42	100.46		100.45[29]	101.16
Sp. gr.	2.64	2.54	...	...	...	2.52	...	...	...	...	...

1. Trachyte of Ragged Hill dome (Vassar, analyst).
2. Trachyte of Southeast Head (Washington, analyst).
3. Trachyte of Cross Hill, quarry (Reinisch, analyst).
4. Trachyte from a point half-way up Green Mountain (Reinisch, analyst).
5. Trachyte from a point "north of Dark Slope" (Reinisch, analyst).
6. Rhyolite (quartz trachyte), flow from White Hill (Radley, analyst).
7. " Trachyte " from Weather Post (Klement, analyst).
8. Pumice from foot of Riding School cone (Reinisch, analyst).
9. " Alkalitrachyt-Perlit," from stream-course north of the Riding School School (Reinisch, analyst).
10. Trachytic tuff, southwest part of the Riding School (Reinisch, analyst).
11. Obsidian from Green Mountain (Klement, analyst).

Column 1 of Table XI gives the average of the analyses of Ascension basalts, which may be compared with the average plateau basalt, with the average of 198 basalts (including some plateau basalts and many

[29] Includes 3.17 per cent of salts soluble in water.

from central eruptions), and with the average basalt of Hawaii. Columns 1 and 2 of Table XII permit similar comparison with the average basalt of Tutuila Island in the Samoan chain of volcanoes (five analyses by H. S. Washington, given in the writer's "Geology of American Samoa," Pub. No. 340, Carnegie Institution of Washington).

TABLE XI.

COMPARISON OF AVERAGE ANALYSES OF BASALTS.

	1	2	3	4
SiO_2	49.68	49.35	49.87	49.04
TiO_2	2.76	2.59	1.38	2.92
Al_2O_3	16.13	14.05	15.96	13.64
Fe_2O_3	4.02	3.40	5.47	2.99
FeO	7.47	9.94	6.47	8.89
MnO	.24	.21	.32	.12
MgO	5.33	6.36	6.27	8.53
CaO	8.78	9.73	9.09	9.52
Na_2O	3.70	2.90	3.16	3.00
K_2O	1.31	1.00	1.55	.86
P_2O_5	.58	.47	.46	.49
	100.00	100.00	100.00	100.00

1. Average of three basalts from Ascension Island.
2. Average of fifty analyses of plateau basalts, including: eleven Deccan basalts, six Oregon basalts, and thirty-three Thulean basalts (from H. S. Washington, Bull. Geol. Soc. America, **33**, 797, 1922).
3. Average of 198 analyses of basaltic rocks, published before the year 1910; world-wide distribution.
4. Average of fifty-four analyses of mafic rocks in Hawaii, weighted as follows: equal weights given to respective averages of twelve from Kohala, twelve analyses from Mauna Kea, six analyses from Hualalai, thirteen analyses from Kilauea, and eleven analyses from Mauna Loa. (See H. S. Washington: reference under "2".)

Note: all averages calculated as water-free and to 100 per cent.

The degree of similarity of all these averages illustrates once more the relative uniformity of common basalt throughout the world. This material may vary in composition somewhat as it is traced from its position beneath the continental crust to its position beneath the

sub-Pacific crust, but these variations are too slight to have yet been detected with full certainty. However, it seems clear that the eruptible part of the Sima is everywhere of basaltic character.

The proof of the existence of common basalt in Ascension is an important fact which must modify the impression given by a statement of Reinisch, who, working with a relatively small collection of specimens and without the advantage of a prolonged reconnaissance of the island, announced that all of the specimens collected in Ascension by the Deutsche Südpolar Expedition are "durchweg Alkaligesteine" (page 646 of his paper). According to the general consensus of opinion among petrographers, the basalts of Ascension have both chemical and mineralogical characters which must place them in the calc-alkaline or subalkaline group of rocks.

TABLE XII.

Comparison of Ascension Lavas with those of Tutuila, Samoa.

	1	2	3	4	5	6	7	8
SiO_2	49.68	48.44	52.65	52.34	65.71	66.38	71.73	70.80
TiO_2	2.76	4.29	2.00	2.99	.43	.65	.25	.26
Al_2O_3	16.13	13.27	16.61	16.66	15.40	17.00	12.82	12.73
Fe_2O_3	4.02	4.06	4.52	2.80	3.46	2.12	3.60	4.03
FeO	7.47	8.27	4.77	5.67	1.12	1.33	.05	.28
MnO	.24	.15	.37	.07	.22	.05	.29	.06
MgO	5.33	8.21	3.91	3.39	.27	.29	.18	.04
CaO	8.78	7.72	7.29	5.58	1.07	1.62	.60	.50
Na_2O	3.70	3.47	4.61	4.24	6.36	5.35	5.31	5.77
K_2O	1.31	1.55	2.05	2.38	4.96	4.47	4.77	5.28
H_2O	...	...	.70	2.63	.91	.64	.35	.25
P_2O_5	.58	.57	.52	1.25	.09	.10	.05	None
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1. Average of three analyses of Ascension Island basalts, calculated as water-free.
2. Average of five analyses of Tutuila Island basalts, calculated as water-free.
3. Trachydoleritic basalt from Ascension Island; one analysis.
4. Trachydoleritic basalt from Tutuila Island; one analysis.
5. Average of five analyses of Ascension Island trachytes.
6. Average of two analyses of Tutuila Island trachytes.
7. Quartz trachyte (rhyolite) from Ascension Island; one analysis.
8. Quartz trachyte (rhyolite) from Tutuila Island; one analysis.

In Table XII, columns 1, 3, 5, and 7, are entered the average analyses of the important types of lava in Ascension. The variation is systematic and is strikingly parallel to that shown in the averages of Washington's analyses of the rocks of Tutuila, Samoa (columns 2, 4, 6, and 8). The volcanic complex of the island in the western Pacific thus exemplifies the same process of differentiation as the process responsible for the variety of lavas in a mid-Atlantic island. The table suggests that trachydolerite and trachyandesite represent stages in the development of trachyte from basalt. Attention may therefore be concentrated on the problem of the origin of trachyte.

Leading generalizations which apparently should govern thought on this subject, including facts already noted, are:

1. The close time and space relations of eruptions of trachyte and common basalt;
2. The usual insignificance of trachyte in volume when compared with the accompanying basalt, and, a fortiori, when compared with any one of the basaltic plateaus;
3. The existence of trachydolerite and other volcanic species, transitional from basalt to trachyte;
4. The alternation of eruptions of trachyte and basalt at central vents;
5. The non-existence of great fissure eruptions of trachyte;
6. The observation that trachytic eruptions at central vents seem to be generally preceded by long periods of dormancy;
7. The common heralding of trachytic eruption by major explosions, which show that much hot gas had accumulated at the top of each column of trachytic magma;
8. The great rarity of ordinary bubble-vesicles in trachytes, except in quite subordinate, pumiceous phases;
9. The high viscosity of trachytes, with resulting tendency for the formation of endogenous domes or crater-fillings as well as short, thick flows;
10. The correlated fine grain of most trachytes;
11. Repeated instances of transition from trachyte to more rhyolitic lava, and, in other regions, to phonolite;
12. The rather common development of micropoikilitic quartz in trachytes;
13. The not uncommon association of trachytes with limburgites and other highly mafic lavas.

The rules numbered 1, 2, 3, and 4 are obviously obeyed at Ascension and have already been emphasized. Few other regions illustrate more

clearly, or with so many examples, intimacy between trachyte and basalt.

In the nature of the case the fifth rule cannot be well tested by the data from a single island. On the other hand, practically all of the trachytic bodies of Ascension have issued from central vents, suggesting, here as elsewhere, that the formation of trachyte is connected with processes operating in volcanic pipes.

A word may be added concerning rules 6 and 7. Wherever the base of a trachytic flow could be seen in the island, that flow was seen to rest on an explosion-breccia, which includes fragments of both trachyte and the older basalts. The corresponding explosions are most reasonably dated at times immediately preceding the respective outflows of the massive trachyte. Similar examples have been recently mapped by the writer in the island of Tutuila, Samoa. The accumulation of sufficient gaseous pressure at each of these central vents logically demands an earlier, prolonged period of dormancy.

With few exceptions, rules 8, 9, and 10 appear to be general for the world.

From their field relations the rhyolitic obsidians of Ascension are thought to represent a segregation of small volumes of silica-rich magma at the tops of the columns of trachyte in the magmatic state. Thus, along with the abundant water-gas and other gases which were assembled just under the volcanic plugs during dormancy, silica was somewhat concentrated. The result has been the formation of a quartz-trachyte type of obsidian approaching the comendites and pantellerites in composition.

The local development of phonolitic, nephelite-bearing phases in trachyte, like that reported by Washington from Monte Ferru, Sardinia, has not been observed in Ascension.[30]

Even after eruption the Ascension trachyte was affected by the rise of silica-bearing solutions, which were responsible for the micropoikilitic quartz, so often seen in the main body of a trachytic flow and, still more abundantly, in the silicified interfaces already described. In largest part the volatile part of these solutions was probably water.

So far as known, the island bears no visible picritic, limburgitic, or other ultra-mafic lava. The wehrlitic fragments in the trachytic tuffs of Green Mountain represent the only analogy to these types yet discovered.

The foregoing brief review of the relative quantities and the chemi-

30 H. S. Washington, Amer. Jour. Science, **39**, 514, 519, 1915.

cal, structural, and temporal relations of the Ascension lavas can hardly fail to suggest a conclusion as to the origin of the salic types: basalt is the source magma; trachyte, its derivative. There appears to be no ground for assuming a special "alkaline" basalt, rather than common basalt, as the primary magma.

The development of rhyolitic phases at the tops of the trachytic columns of magma indicates gravitative separation of the units of differentiation, whether solid or fluid. Gravity so clearly controls the differentiation of intrusive magmas that one is justified in postulating its great importance at Ascension, though, as at all volcanic centers, full and direct evidence is not to be expected.

The theory of pure fractional crystallization, which premises the gravitative removal of solid phases with fall of temperature, has usually been phrased in terms of an initially liquid system, uniformly cooled in all parts. However, magma resting in the earth's crust is not likely to cool at a uniform rate in either vertical or horizontal planes. The more rapidly chilled phase near the contact should undergo some fractional crystallization before the central part of the magma has been at all crystallized because of cooling. The residual liquid of the peripheral phase is less dense than the original magma, which therefore tends to replace the new liquid phase, driving it upwards in the magma chamber. The result is a kind of convection in the chamber, concentrating increasingly salic liquid at the top. This vertical motion of the residual liquid is a secondary but important consequence of the sinking of the early-formed crystals. The shape of the chamber, especially the inclination of its walls to each other and to the vertical, is likely to affect the speed of the concentration of the residual liquid.

If the magma chamber in which trachyte has been developed has in depth a cross-section considerably greater than the cross-section of the pipe filled with trachyte, the original magma vertically below the pipe would be relatively little affected by the sinking of crystals. The extrusion of the trachyte must be accompanied by the rise of this basalt, which may soon follow the trachytic magma to the earth's surface. Herein perhaps may be a basis for explaining the observed sequence — basalt, trachyte, basalt — at Green Mountain and at Cross Hill.

The trachyandesite flooding the trachyte of Southeast Head may represent the lower, more femic phase of the same body of differentiated magma which first welled out as trachyte; or the trachyandesite may be a new differentiate of basalt, following up the erupted trachyte. A choice between these alternatives does not seem possible. In either case, however, the relation of the trachyandesite to the trachyte does

not offer any special difficulty for the theory of fractional crystallization.

Pyroxene andesites appear to be direct differentiates of common basalt and they are much more voluminous than trachyte. This fact has suggested that the differentiation of trachyte may be due to a condition not normally dominating at basaltic vents of the central type. The condition described has been speculatively found in the special concentration of volatile constituents, notably water and carbon dioxide, at trachytic vents. It is reasonable to suppose that water-gas and carbon dioxide may be absorbed by magma from the walls of its chamber, and the writer is inclined to favor the hypothesis that resurgent gas is a leading factor in the differentiation of highly alkaline phases.

That the trachytes are commonly, if not always, associated with the rise of much volatile matter into volcanic pipes is indicated by the high explosiveness of the upper part of each column of trachytic magma. Just before eruption the lower, greater part of each column is apparently quite poor in dissolved gas, as shown by the high viscosity and the fine grain of all the trachytes and by the general lack of bubble-vesicles in domes and flows of trachyte. Thus the gases seem to have continued to stream upward through the column. The common phenomenon of feldspathization of the country rocks at plutonic contacts suggests that feldspathic material will be dissolved with the gases; carried to the limit a trachytic magma would result.

If the Ascension trachytes originated in that way, their differentiation must have taken much time and the emanating gas must have had great total volume. The xenolithic granite in the trachyte of the Crags dome and the granitic fragments in the agglomerate of Green Mountain were probably derived from the terrane underlying the Ascension cone. If so, the trachytic magma stood in columns perhaps 2,000 meters high. Like most eroded volcanic necks, these columns doubtless had small cross-sections to considerable depths. To supply the material for any one of several domes and outflows, such as Weather Post and Southeast Head, the slender columns must have been long, possibly measuring more than 2,000 meters vertically.

To permit of such drastic differentiation on the large scale, in spite of the comparatively rapid loss of heat along the walls of each vent, an abundant upward stream of fluxing gas, active for a long time, seems to be essential. Moreover, to be effective, the rising gas must itself have had a decidedly high temperature. That all of this gas did not directly escape into the air is shown by the rule of explosion just before most, if not all, of the trachytic eruptions took place.

The study of the Ascension trachyte has thus led to a sympathetic reception of the following hypotheses: (1) that the trachyte is a differentiate of common basalt; (2) that the differentiation has been dependent upon the upward movement of fluids, both liquid and gaseous; and (3) that the active gas, probably water-gas, was largely of resurgent nature, that is, derived from the rocks surrounding the various vents. These hypotheses are consistent with the view that fractional crystallization has also played an important rôle in the generation of the salic magmas from basalt. No evidence of induced liquid immiscibility in the basaltic magma has been discovered, but the writer is not prepared to deny its participation. On the other hand, fractional crystallization under the conditions of nature (see page 77) seems to imply the progressive, gravitative separation of liquid phases, even if those phases are perfectly miscible.

Summary.

Darwin's account of Ascension Island is accurate and thorough to such a degree that all later descriptions must be in a sense but supplementary to his. Yet modern volcanology and petrology demanded a considerable addition to Darwin's picture. The staff of the *Challenger*, Renard, Prior, the staff of the Deutsche Südpolar Expedition, and Reinisch have filled many gaps, but more detailed mapping and further chemical study of this remarkable island have remained highly desirable. The reconnaissance map, Plate I, and seven new rock analyses, by Washington, Vassar, and Radley, are among the principal contributions of this paper.

The types of lava are now seen to include a chemical series beginning with common olivine basalt and passing through olivine-free basalt, trachydoleritic basalt, trachydolerite, andesite (?), and trachyandesite to alkaline trachytes and alkaline quartz-trachyte ("rhyolite"). The series is in principle identical with that recently demonstrated for the volcanic composite at Tutuila, Samoa; thus illustrating the rule of one law in the differentiation of lavas, whether this took place at a mid-Atlantic center or at an almost antipodal center in the western Pacific.

The most striking features of Ascension are a dozen endogenous domes or crater-fillings of trachyte (with occasional quartz-trachyte and obsidian phases), some of which have magnificent outflowing tongues of the same lava. The recency and largely unmodified forms of these eruptions give them special importance in connection with

the problems of origin and emplacement of trachytes. The intimacy of the association between the trachytes and common basalt is very evident. A possible mode of the derivation of the trachyte from basaltic magma, founded on a modified form of the fractional-crystallization theory, is briefly sketched.

Among the more detailed results of this investigation may be mentioned: the evidence of pronounced vertical, axial subsidence of the lava columns in the Riding School, "Drip," and East Craters; the suggestive sliding phenomenon connected with the basaltic flows; the description of the spectacular fissure-eruption of trachyandesite at Southeast Head; the listing of fifteen plutonic types, including quartz-bearing species, among the volcanic projectiles; the discovery of xenolithic granite in the trachyte of "The Crags" dome, with its suggestion of the considerable depth at which trachyte is differentiated in a volcanic pipe; the enforced emphasis on the problem of silicified interfaces and of micropoikilitic quartz in the trachytes; the repeated proofs that ordinary vesicles of bubble form are absent from the greater part of each trachytic mass; many new illustrations of the high viscosity characterizing trachytic magma at the time of its eruption; and the repeated occurrence of "rhyolitic" obsidian and pumice in such relations as to show that the trachytic magma in each vent was capped by a specially silicious and hydrous, explosive solution.

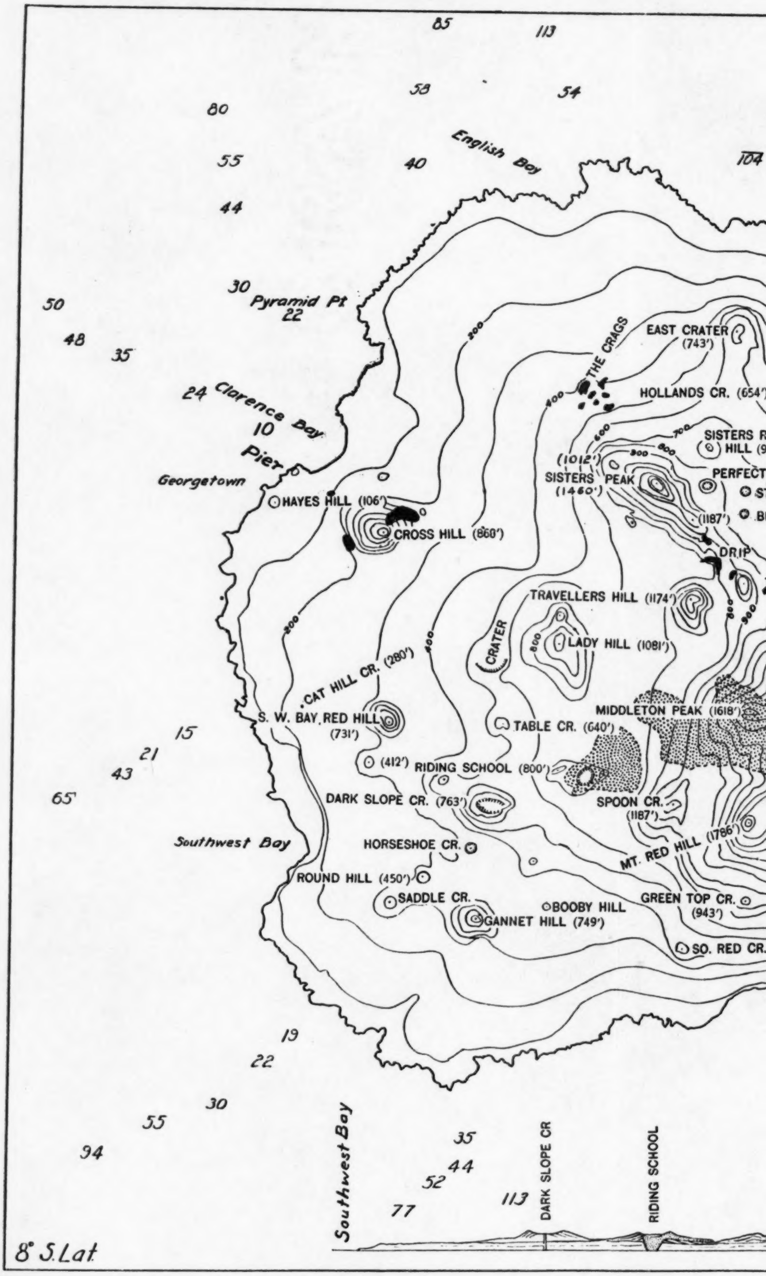
The compilation of significant data from the writings of Renard, Prior, and Reinisch along with the new findings have lengthened this paper, but have clearly increased its value for petrologists who desire a record of all trustworthy chemical analyses of the Ascension rocks.

Harvard University
Cambridge, Massachusetts

ILLUSTRATIONS.

PLATE I.

Geological Sketch Map of Ascension Island.


English Bay
Pyramid Pt
Clarence Bay
Pier
Georgetown
HAYES HILL (106')
CROSS HILL (860')
THE CRAGS
EAST CRATER (743')
HOLLANDS CR. (654')
SISTERS PEAK (1460')
(1012')
(1187')
DRIP
TRAVELLERS HILL (1174')
CRATER
LADY HILL (1081')
CAT HILL CR. (280')
S. W. BAY RED HILL (731')
TABLE CR. (640')
MIDDLETON PEAK (1618')
(412')
RIDING SCHOOL (800')
DARK SLOPE CR. (763')
SPOON CR. (1187')
Southwest Bay
HORSESHOE CR.
MT. RED HILL (1786')
ROUND HILL (450')
SADDLE CR.
BOOBY HILL
GANNET HILL (749')
GREEN TOP CR. (943')
SO. RED CR.
Southwest Bay
DARK SLOPE CR
RIDING SCHOOL
8° S. Lat.

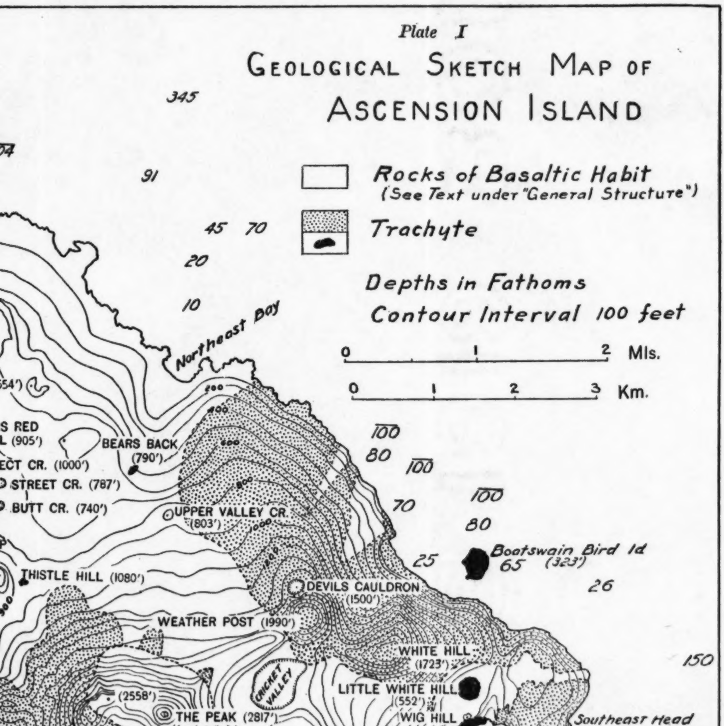


Plate I
GEOLOGICAL SKETCH MAP OF
ASCENSION ISLAND
Rocks of Basaltic Habit
(See Text under "General Structure")
Trachyte
Depths in Fathoms
Contour Interval 100 feet
0 1 2 Mls.
0 1 2 3 Km.
Northeast Bay
BEARS BACK (790')
UPPER VALLEY CR. (803')
THISTLE HILL (1080')
DEVILS CAULDRON (1500')
WEATHER POST (1990')
WHITE HILL (1723')
LITTLE WHITE HILL (552')
WIG HILL
CRICKET VALLEY
THE PEAK (2817')
(2558')
GREEN MT.
CRATER CLIFF (186')
Boatswain Bird Id (323')
Southeast Head
Southeast Bay
SOUTHEAST CR. (1146')
RAGGED HILL (944')
Crystal Bay
Cocoanut Bay
Pillar Bay
STREET CR. (787')
BUTT CR. (740')
THE PEAK
CRICKET V.
LITTLE WHITE HILL
Southeast Head

PLATE II.

FIGURE *A*. Panorama of Ascension Island, looking southeast from anchorage at Georgetown; from photograph.

FIGURE *B*. Looking west from Green Mountain road; left, lower slope of Lady Hill; middle, Cross Hill; right, young basaltic flow which issued from base of Sisters Peak.

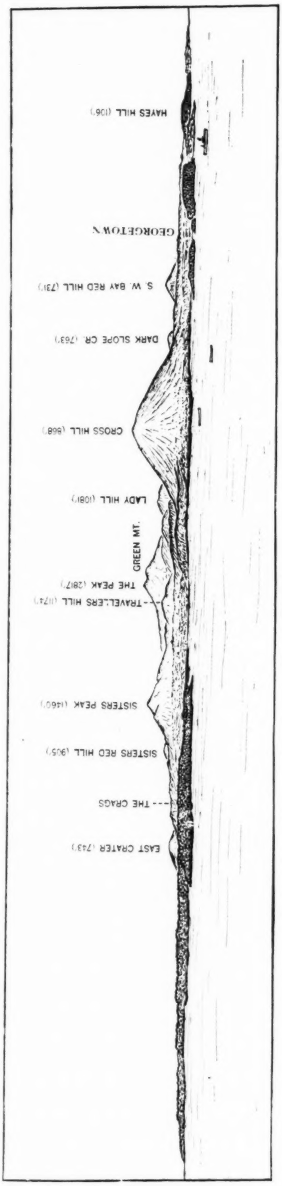

HAYES HILL (106')
GEORGETOWN
S. W. BAY RED HILL (731')
DARK SLOPE CR. (763')
CROSS HILL (868')
LADY HILL (1081')
GREEN MT.
THE PEAK (2817')
TRAVELLERS HILL (1174')
SISTERS PEAK (1460')
SISTERS RED HILL (905')
THE CRAGS
EAST CRATER (743')

Fig. A

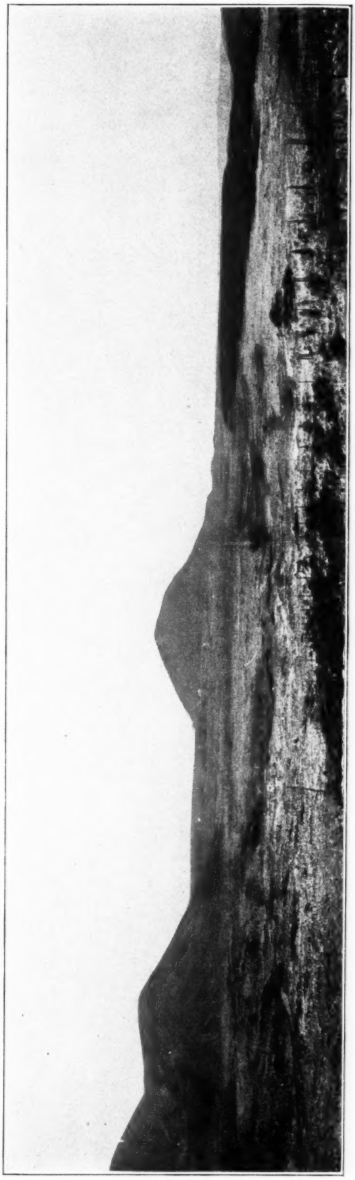


Fig. B

PLATE III.

FIGURE *A*. Sisters Peak (right) and East Crater (left), seen from Governor's house, Cross Hill.

FIGURE *B*. Young basaltic flow which issued from a vent west of East Crater. Looking north from Cross Hill; Pyramid Point in the distance; calcareous-sand beach of Clarence Bay in foreground.

Fig. A

Fig. B

PLATE IV.

Panorama from a low level on Green Mountain, showing various craters, Bears Back, and a young basaltic flow from Sisters Peak (midground); slope of Thistle Hill, left, foreground.

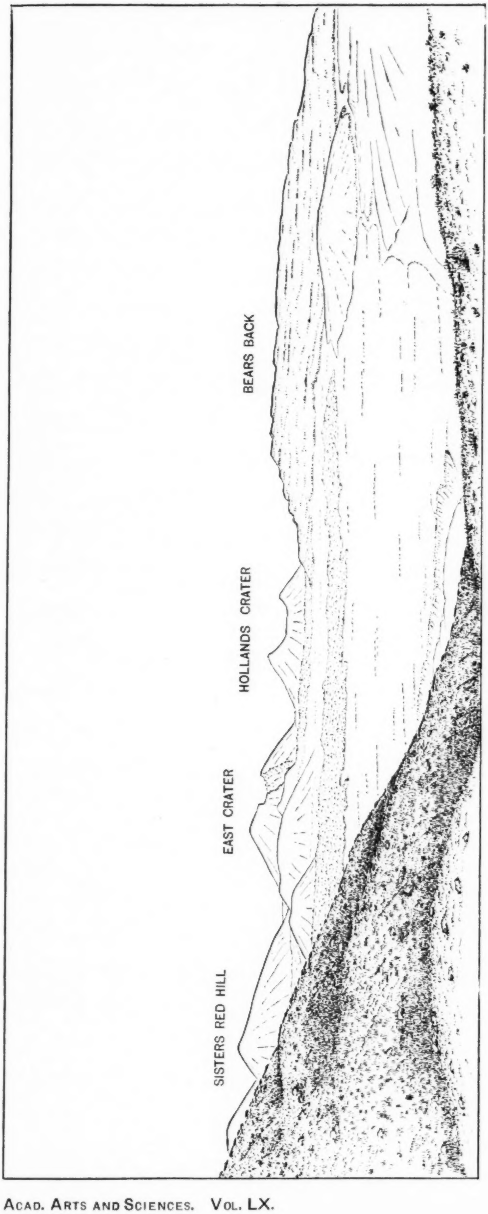

SISTERS RED HILL
EAST CRATER
HOLLANDS CRATER
BEARS BACK

PLATE V.

FIGURE *A*. Characteristic rough, constructional surface of young basaltic flow, cliffed by the waves.

FIGURE *B*. Hornito-like conelets on back of young basaltic flow, near Wireless Station.

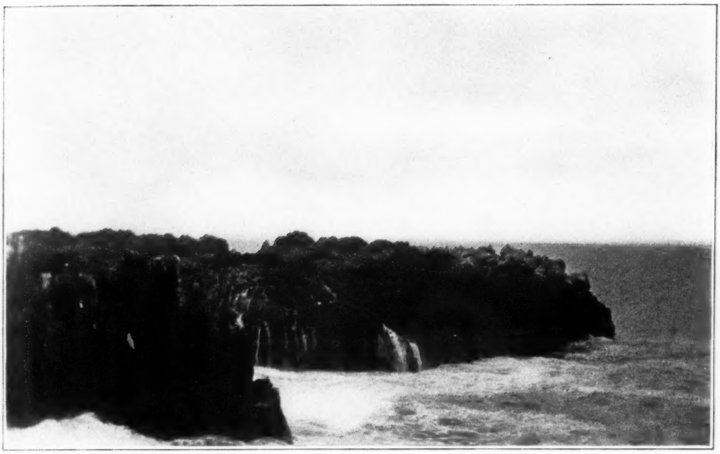


Fig. A

Fig. B

PLATE VI.

FIGURE *A*. Weathered-out silicious "veins' in trachyte, top of Ragged Hill dome; undercutting of the softer trachyte by the wind.

FIGURE *B*. Rough, flat-lying, silicious "vein" projecting from the softer trachyte, Riding School; the hoodoo-like form is about two meters high.

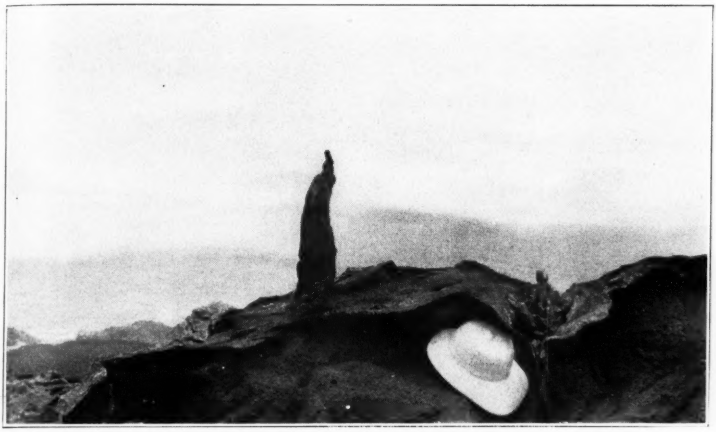
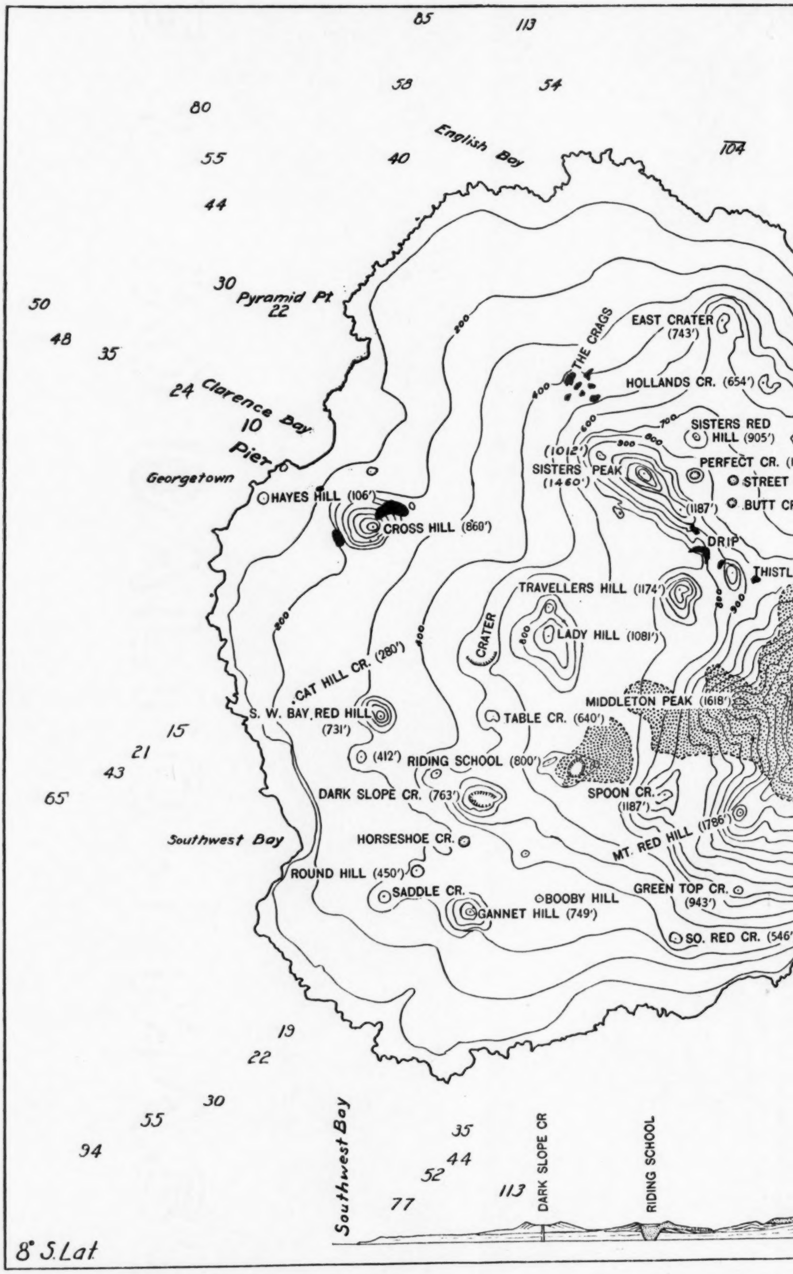


Fig. A

Fig. B

PLATE VII.

Little White Hill dome of trachyte, standing in nearly circular crater-rim of basaltic material (midground and foreground). White Hill dome of trachyte in the background, left. Traced from photograph.


English Bay
Pyramid Pt
Clarence Bay
Pier
Georgetown
Southwest Bay
EAST CRATER (743')
THE CRAGS
HOLLANDS CR. (654')
SISTERS RED HILL (905')
SISTERS PEAK (1460')
(1012')
PERFECT CR.
STREET
BUTT CR
(1187')
DRIP
THISTL
HAYES HILL (106')
CROSS HILL (860')
TRAVELLERS HILL (1174')
LADY HILL (1081')
CRATER
CAT HILL CR. (280')
MIDDLETON PEAK (1618')
S. W. BAY RED HILL (731')
TABLE CR. (640')
(412') RIDING SCHOOL (800')
DARK SLOPE CR. (763')
SPOON CR. (1187')
MT. RED HILL (1786')
HORSESHOE CR.
ROUND HILL (450')
SADDLE CR.
BOOBY HILL
GANNET HILL (749')
GREEN TOP CR. (943')
SO. RED CR. (546'
Southwest Bay
DARK SLOPE CR
RIDING SCHOOL
8° S. Lat

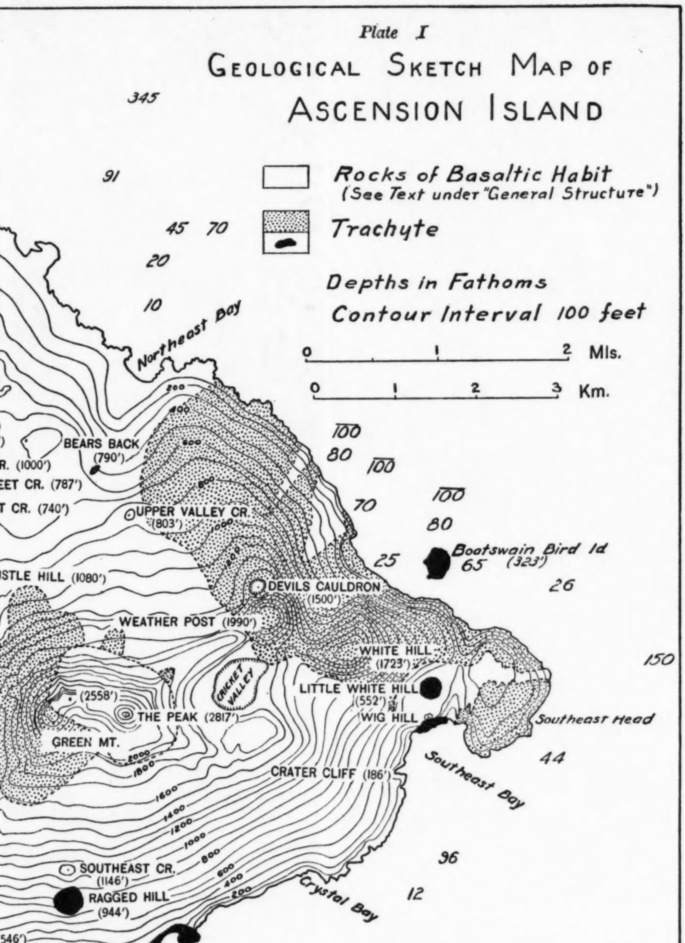


Plate I
GEOLOGICAL SKETCH MAP OF
ASCENSION ISLAND
Rocks of Basaltic Habit
(See Text under "General Structure")
Trachyte
Depths in Fathoms
Contour Interval 100 feet
0 1 2 Mls.
0 1 2 3 Km.
Northeast Bay
BEARS BACK (790')
UPPER VALLEY CR. (803')
DEVILS CAULDRON (1500')
WEATHER POST (1990')
WHITE HILL (1723')
LITTLE WHITE HILL (552')
WIG HILL
THE PEAK (2817')
(2558')
GREEN MT.
CRICKET VALLEY
CRATER CLIFF (186')
SOUTHEAST CR. (1146')
RAGGED HILL (944')
Bootswain Bird Id (323')
Southeast Head
Southeast Bay
Crystal Bay
Cocoanut Bay
Pillar Bay
THE PEAK
CRICKET V.
LITTLE WHITE HILL
Southeast Head

PLATE II.

Figure *A*. Panorama of Ascension Island, looking southeast from anchorage at Georgetown; from photograph.

Figure *B*. Looking west from Green Mountain road; left, lower slope of Lady Hill; middle, Cross Hill; right, young basaltic flow which issued from base of Sisters Peak.

PLATE VII.

Little White Hill dome of trachyte, standing in nearly circular crater-rim of basaltic material (midground and foreground). White Hill dome of trachyte in the background, left. Traced from photograph.

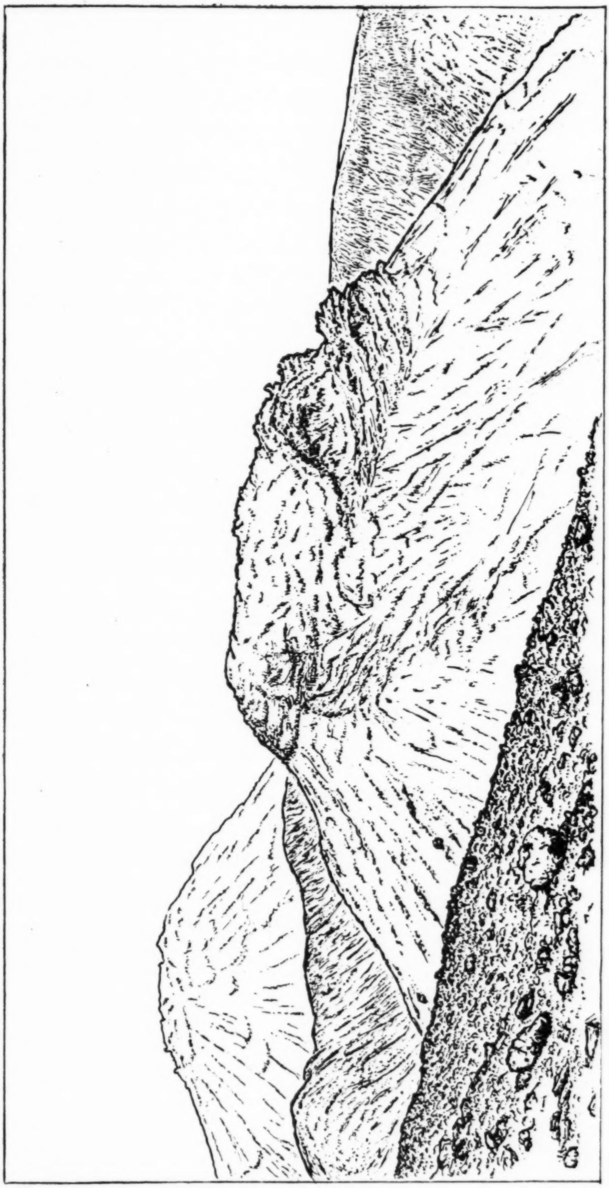


PLATE VIII.

Looking east from near Cricket Valley to: (left) White Hill dome of trachyte with overflow; (midground) Wig Hill dome of trachyte mantled with the basaltic "wig"; (background) Southeast Head dome of trachyte flooded with thin flow of trachyandesite; débris of Cricket Valley explosion in foreground. Drawn from a photograph.

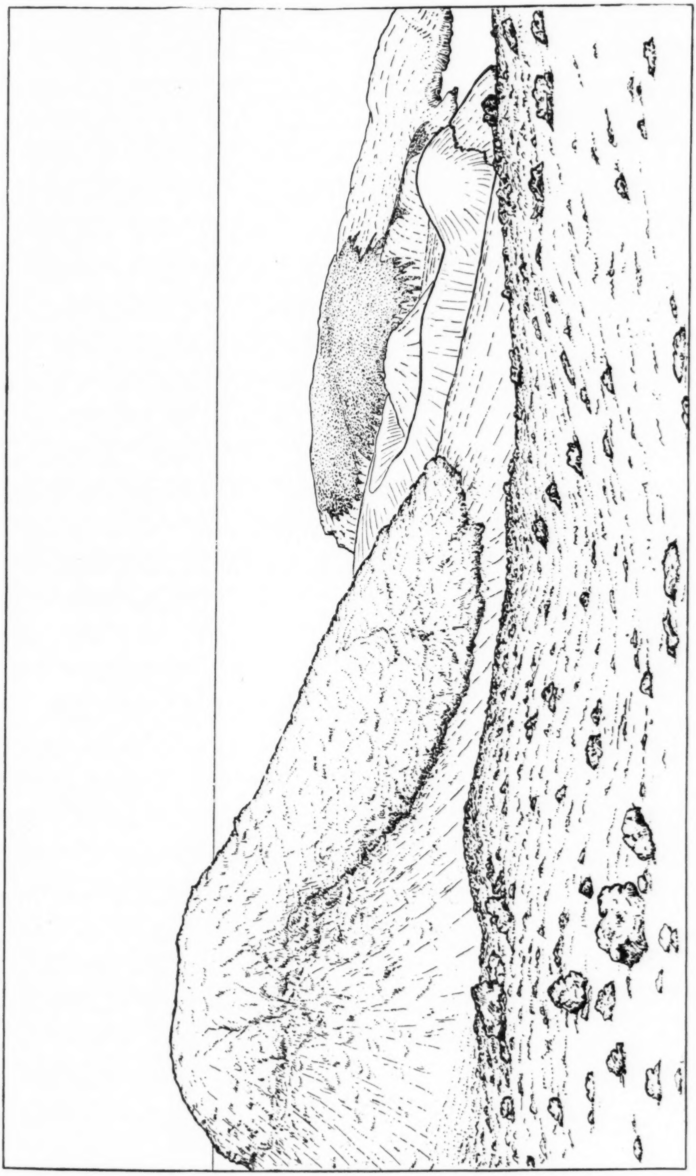


PLATE IX.

Figure *A*. Wig Hill seen from the west; Southeast Head in the background.

Figure *B*. Closer view of the "wig" of basaltic scoria overlying the Wig Hill dome of trachyte.

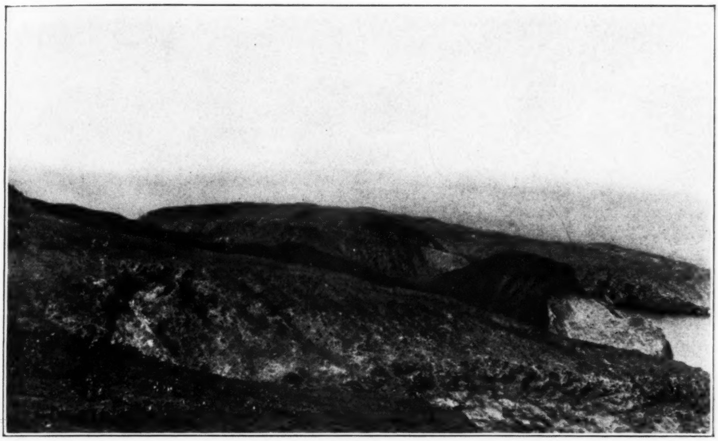


Fig. A

Fig. B

PLATE X.

Figure *A*. Cross Hill from Georgetown, showing basaltic tuff-ash deposit which overlies a core of trachyte (not visible in this view).

Figure *B*. Looking across Riding School crater to Green Mountain (left) and Mountain Red Hill (right); in the crater a thick layer of basaltic tuff overlying well-bedded deposits of dust-like, silicious ash, said to contain silicious "infusoria."

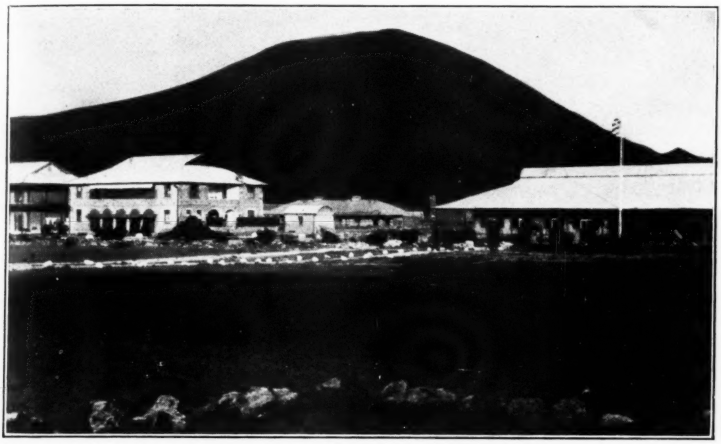


Fig. A

Fig. B

PLATE XI.

Panorama of Riding School crater, looking west from a point on the trachytic rim, across the centripetally-dipping tuff beds and water-laid beds, to the basaltic part of the rim. Near the middle, background, is Dark Slope crater. Structure brought out by the use of ink on the photograph.

PLATE XII.

FIGURE *A*. Basaltic tuff overlying silicious beds, in Riding School crater; hammer 30 cm. long.

FIGURE *B*. Dipping tuff and "lake" beds in Riding School crater.

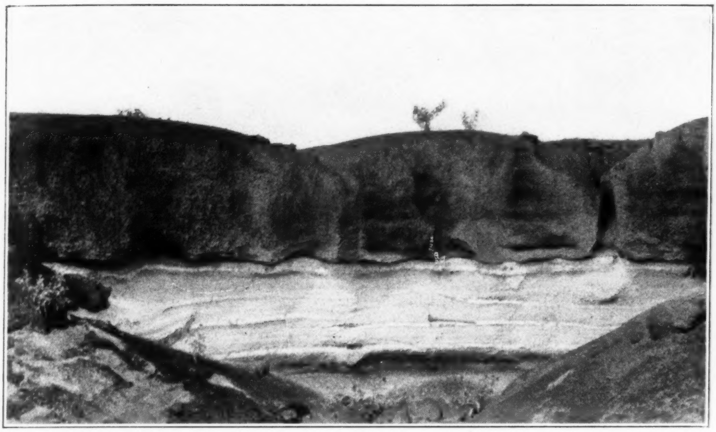


FIG. A

FIG. B

PLATE XIII.

Carious weathering of Riding School trachyte, south side of this dome.

PLATE XIV.

FIGURE *A*. Looking south from road to edge of thick overflow from trachytic dome of Green Mountain (left); Mountain Red Hill, basaltic cone, in background.

FIGURE *B*. Steeply dipping, eroded beds of tuff composing The Peak, which stands in a caldera rimmed with older trachyte of Green Mountain. The black, basaltic tuff of The Peak is beyond the windmill; the crags with paler tint on right are trachyte. Young erosion-valley opened along the contact of trachyte and tuff.

FIG. A

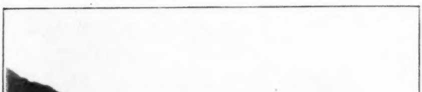


FIG. B

PLATE XV.

FIGURE *A*. Looking across the basaltic tuff-ash slope of Green Mountain to The Weather Post (left) and White Hill (right) domes of trachyte.

FIGURE *B*. Flow-structure and characteristic rough surface of an Ascension Island flow of trachyte; end of flow, southwest side of White Hill.

FIG. A

FIG. B

PLATE XVI.

The Devils Cauldron (Punchbowl), seen from the summit of The Peak; the Cauldron is 2.3 kilometers distant. Photograph by G. H. Wilkins, naturalist to the Shackleton-Rowett Expedition.

PLATE XVII.

Lower end of great trachyte flow from White Hill dome, southwest side. Wig Hill appears behind the flow. Southeast Head trachyte dome in the distance.

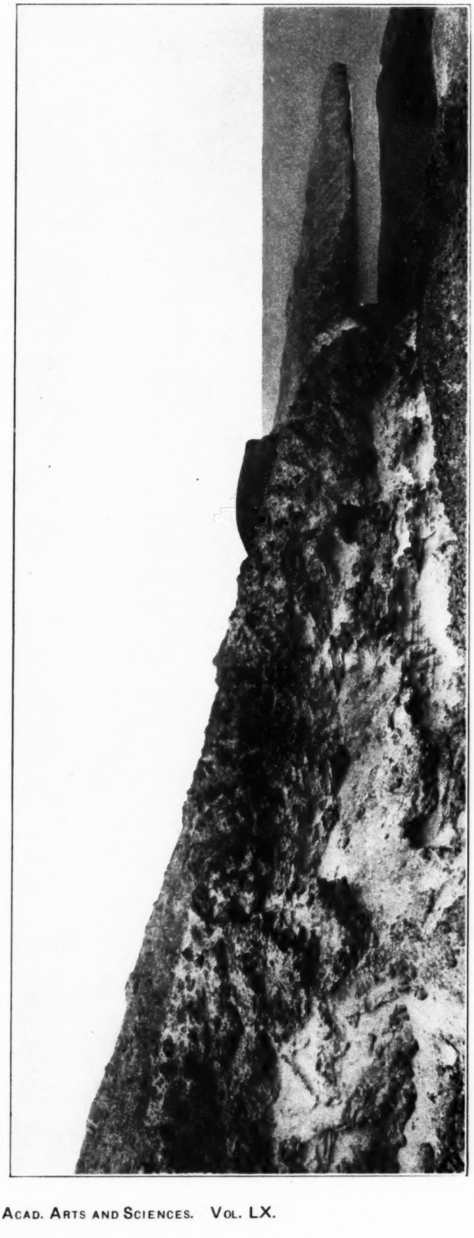


PLATE XVIII.

FIGURE *A*. Southeast Head dome-plateau of trachyte, veneered with a younger flood of trachyandesite, shown in darker tint.

FIGURE *B*. Continuation of view *A*. Sea-cliff of Southeast Bay on the right.

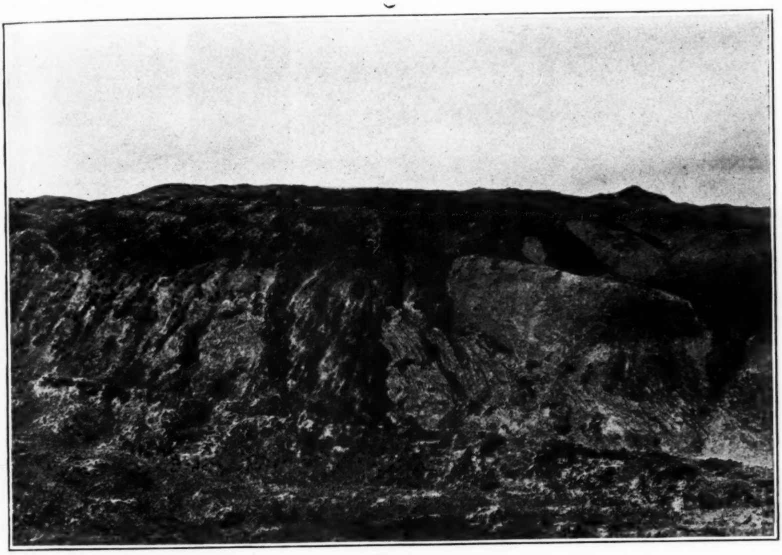


Fig. A

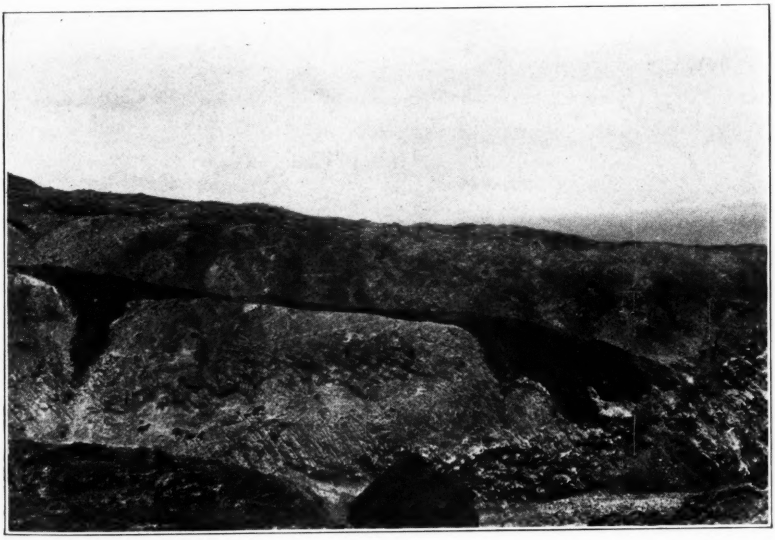


Fig. B

PLATE XIX.

FIGURE *A*. Boatswain Bird islet, seen from high sea-cliff east of the Devils Cauldron.

FIGURE *B*. Sea-cliff, 90 meters high, cut in monolithic trachyte of Boatswain Bird islet, northwest side.

Fig. A

Fig. B

PLATE XX.

Sea-cave cut in trachyte of Boatswain Bird islet, southwest side.

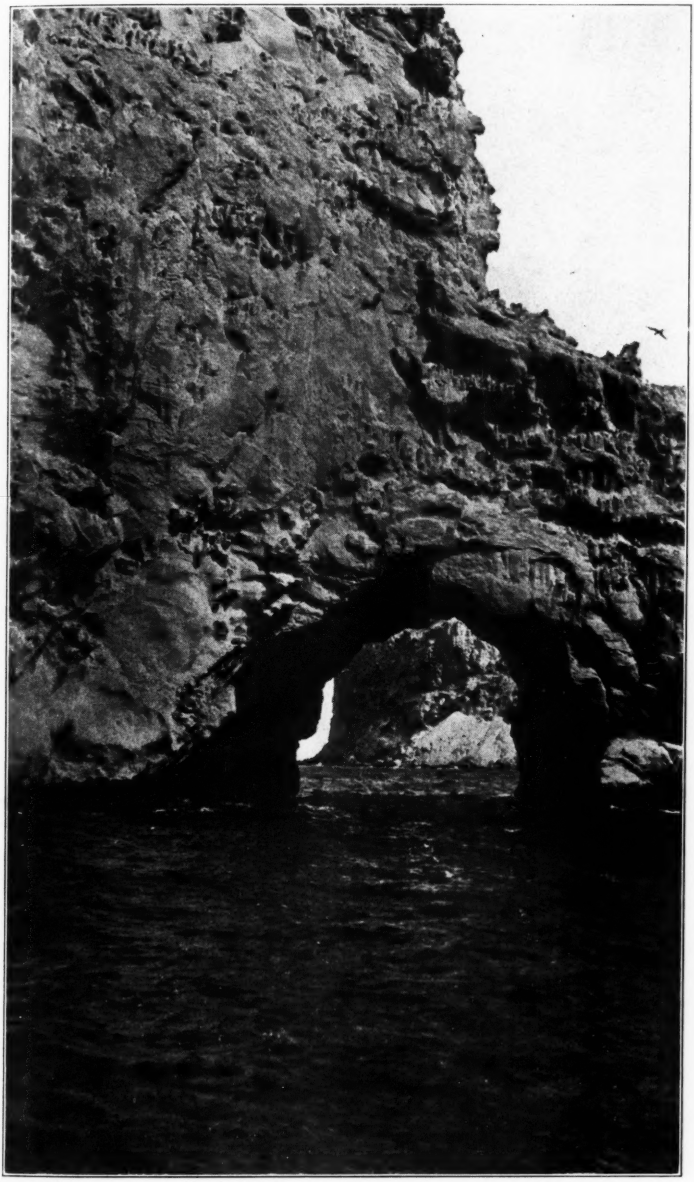


PLATE XXI.

FIGURE *A*. Georgetown; Hayes Hill, a scoriaceous cone of trachydolerite, in background.

FIGURE *B*. View from Cross Hill, over Georgetown, to a low scoriaceous cone of trachydolerite at the Landing Pier.

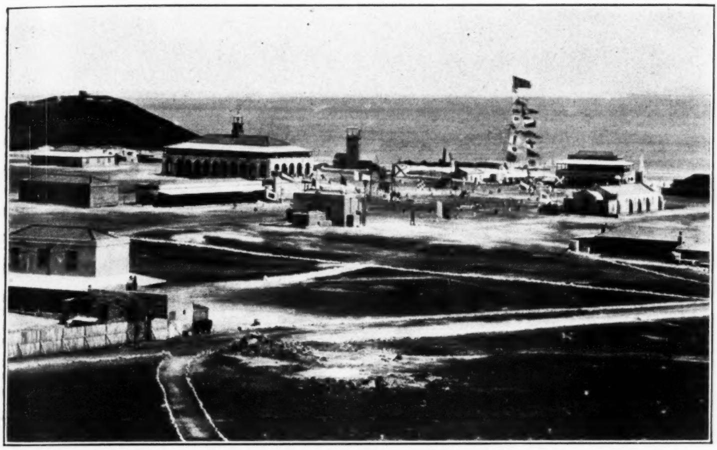


Fig. A

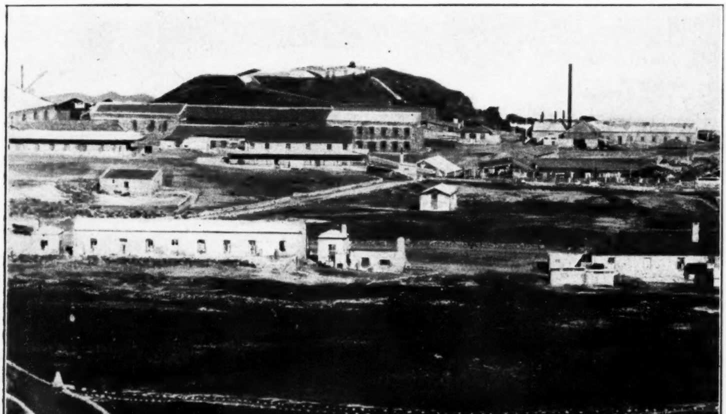


Fig. B